Renewable Energy REAP Academic Partnerships

August 11-14, 2004
Florida Solar Energy Center
Cocoa, Florida

Renewable Energy Academic Partnerships 2003

Arizona State University
Tempe, AZ

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Florida Solar Energy Center

The Florida Solar Energy Center is located in Cocoa, Florida, on Florida's Space Coast. FSEC's New Energy Center is sited on the University of Central Florida/Brevard Community College Campus, and is part of the area's Circle of Science.

The New Energy Center was designed to be "the world's most energy efficient building". Because Florida's climate is very warm and humid, the building must keep people cool and dry without consuming much energy.

The New Energy Center office and lab buildings are designed as long, thin rectangles, rather than squares. This design accomplishes three energy-efficiency objectives:

- Exposes the smallest east and west facing building surfaces to hot morning and afternoon sun
- Maximizes usable space on the building perimeter so daylight can illuminate the interior

- Controls interior air temperatures based on solar exposure (cool south-facing zones without wasting energy cooling the north side, which doesn't need it).

U.S. Department of Energy (DOE)
National Renewable Energy Laboratory (NREL)
Renewable Energy Academic Partnership (REAP) Review Meeting

Seventh Annual Program Review Meeting and "KICK OFF" of the DOE-NREL Minority University Research Associates (MURA) Program for Solar Technology

Florida Solar Energy Center (FSEC)
Cocoa, Florida

August 11–13, 2004

Wednesday, August 11, 2004
FSEC Auditorium

8:00–8:30 a.m.	***……. Registration and Continental Breakfast …….*** (Late Visual Presentation Submission on CDs/zip disks, Poster set-up)
8:30–10:25 a.m.	***Opening Ceremony*** Moderator, Ms. Kenyatta Williams, Southern University MURA Research Associate
8:30 a.m.	***Welcome to Florida Solar Energy Center & Acknowledgments***
8:35 a.m.	***Welcome to REAP 2004*** Dr. Robert McConnell, PV Exploratory Research Project Leader, National Center for Photovoltaics, NREL
8:40 a.m.	***DOE/NREL HBCU Photovoltaics (PV) Research Associates Program /Presentation of Faculty*** Fannie Posey Eddy, NREL – MURA Project Leader
8:45 a.m.	***FSEC Renewable Energy Program*** Dr. Neelkanth Dhere, Principal Research Scientist Florida Solar Energy Center (A Research Institute of the University of Central Florida)
9:00–9:10 a.m.	***……. Break/ Poster Set-up …….***

9:10–10:30 p.m.	***Symposium:*** ***Strengthening Minority Serving Institutions (MSIs) and Preparing Students for Roles in Renewable Energy Technology Research and Leadership***
	Speaker/Moderator: **Dr. Harmohindar Singh**, *Director, College of Engineering, North Carolina A&T University, "Center for Energy Research and Technology"*
	Mr. Frank Stewart, *Chairman of the Board of Directors, Strategic Environment Project Pipeline (StEPP)*
	Dennis McGee, *CEO Envirotech Enterprise Inc.Sustainable Energy and Environmental Center Partnership*
	Joyce Lattimore, *Director, Texas Southern University REEP Program*
	Rita Forman*, Director, Center for Applied Research in Educational Technology*
10:30–10:35 a.m.	**……. *Break* …….**
10:35–12:00 noon	***Technical Presentations and Poster Session*** Moderator, Ms. Kara Broussard, Southern University MURA Research Associate
10:35–11:35 a.m.	***Fisk University, Dr. Richard Mu, Principal Investigator***
	Development of Quantum Dot-Sensitized ZnO and TiO_2 Nanorod Array Solar Cells D. Jowhar, D. O'berry, E. Ojomo, I. Adebiyi, O. Ajiboye, A. Ueda and R. Mu
	Fabrication and Characterization of TiO_2 Nanorods for Nanocomposite Solar Cells D. Jowhar, A. Ueda and R. Mu
	Fabrication and Characterization of ZnO Nanostructures for a Novel Solar Cell Development D. O'Berry, A. Ueda, and R. Mu
	Fabrication and Characterization of Gold and ZnO Thin Films for Nanocomposite PV Devices E. Ojomo, A. Ueda, and R. Mu
	Fabrication and Characterization of Indium Tin Oxide for PV Cells I. Adebiyi, A. Ueda, and R. Mu
	Optical Properties of Nanolayerd Polymers for Potential PV Substrate Development O. Ajiboye, A. Ranade, and R. Mu
11:35–11:40 a.m.	**……. *Break/ Poster Set-up* …….**
11:40–12:00 noon	***Fabrication, Characterization and Modeling of Solar Cells***

Dr. Gregory Lush, Principal Investigator, University of Texas El Paso

12:00–1:00 p.m. ***……. Luncheon ……. FSEC Visitor's Center***

Moderator: Kara Broussard, Southern University, MURA Research Associate

Guest Speaker: **Dr. Lawrence Kazmerski,** Director, National Center for Photovoltaics, National Renewable Energy Laboratory (NREL)

1:00–1:15 p.m. ***……. Break/ Poster Set-up …….***

1:15-5:30 p.m. ***Technical Presentations***
Moderators**: Jauna Ameiva,** University of Texas at Brownsville
Kim Rhone, Southern University

1:15–2:30 p.m. ***NREL MURA Internships***

National Household Power Projections along with the Potential of Solar Methanol Production
Kara Broussard, Southern University and Lawrence L. Kazmerski, NREL

Optical Processing (OP) Using Spectrally Selected Light to Heat Semiconductor Wafers
Kenyatta Williams, Southern University

Anti-Reflective Coating Thickness Variation in a Single Measurement using new GT-FabScan 6000 Reflectometer
Juana Ameiva, University of Texas at Brownsville

Temperature Distribution Through Optical Heating
Drake Broussard, Southern University

A Broadened Horizon: High Performance PV for a High Performance World
Clarisse Steans, North Carolina Central University

2:30–2:35 p.m. ***……. Break …….***

2:35–3:35 p.m. ***NREL MURA Internships***

Hydrogen Production through the use of a System Utilizing High-Concentrator Photovoltaics (HCPV) and Solid Oxide Electrolyzer Cells (SOEC)
Jamal R. Thompson, Howard University

Development of an Efficient Polishing Procedure for Cadmium Telluride and Copper Indium Selenide Using Atomic Force Microscopy
Azael Mancillas, University of Texas at Brownsville

Hawaii Electric Company (HECO) Solar Water Heating Program: Analysis of Solar Water Heater System Installation Inpection Data and Warranty Claims Data
Kim Rhone, Southern University

	The Dissemination of Knowledge: Scientific Database Janie McClurkin, North Carolina A&T State University
3:35–3:40 p.m.	***……. Break …….***
3:40–4:10 p.m.	***Howard University, Dr. James Momoh, Principal Investigator***
	Design and Implementation of PV Based Power Management Scheme Ayodele Ishola-Salawa and Chinedu Onyegbula, Howard University
4:00–4:30 p.m.	***University of Texas at Brownsville, Dr. Manuel Blanco, Principal Investigator***
	Overview of the Tonatiuh Software Development Effort **Dr. Manuel Blanco, University of Texas at Brownsville**
4:30–5:30 p.m.	***Tour of FSEC***
5:30–6:45 p.m.	***Student Poster Reception* - FSEC Auditorium (Judging Student Posters** *only)*

Thursday, August 12, 2004
FSEC Auditorium

8:00–8:30 a.m.	***……. Continental Breakfast …….***
8:30 a.m.–12:35 p.m.	***Continue Technical Presentations*** ***Moderator:* Janie Denise McClurkin,** North Carolina A&T State University
8:30–9:30 a.m.	***Southern University, Dr. Rambabu Bobba, PI*** ***Energy Conversion and Storage Devices: Solar Energy Education and Research,*** Dr. Rambabu Bobba, Principal Investigator, Southern University, Baton Rouge, LA
	UV-VIS-NIR Diffuse Reflectance Measurements of Nanocrystalline Photocatalysts Sean Hall, Southern University
9:30–9:40 a.m.	***……. Break …….***
9:40–10:40 a.m.	***North Carolina Central University, Dr. J.M. Dutta, Principal Investigator***
	Investigation of Photovoltaic and Thermophotovoltaic Semiconductors J. M. Dutta, (PI), North Carolina Central University
	Residual Stresses Modeling In Thin Film And Quantum Dots Misty Green, North Carolina Central University
	Pulsed Laser Deposition of Microcrystalline Silicon J. Estavez, North Carolina Central University

	Numerical Simulations of Residual Stresses in Quantum Dots, Multi-Layer Thin Films of Semiconductor Nano-devices Kai Wang, North Carolina Central University
10:40–11:00 a.m.	***North Carolina A&T State University, Dr. G. Shahbazzi, Principal Investigator*** ***Solar Photovoltaic Power Generation Demonstration Project at NCA&TSU*** Cynthia Prince and Dr. Ghasem Shahbazi, North Carolina A&T University
10:50–11:00	***……. Break …….***
11:00 a.m.–12:30 p.m.	**Professional Development Workshop:** **"Get Up with Something on Your Mind!"** ***Moderator:*** **Ms. Clarisse Steans,** North Carolina Central University MURA Research Associate ***Guest Speaker*** – **Howard Adams, *H.G. Adams Associates***
12:30–1:30	***Luncheon with Speaker - FSEC Visitor's Center*** ***Moderator:*** **Azael Mancillas,** Univ. of Texas at Brownsville ***Guest Speaker:*** **Mr. Steve Grey, *Director for Indian Affairs Intergovernmental and External Affairs, Office of Congressional and Intergovernmental Affairs, U.S. Department of Energy***
1:30–1:35	***……. Break …….***
1:35– 5:15	**Technical Sessions – Moderator: Clarisse Steans,** North Carolina A&T State University
1:35–2:45	***Developing Careers in Renewable Energy Symposium*** ***Guest Speaker and Moderator –*** **Karla Horton,** Southern University **Karla Horton,** Southern University **Dr. Ryan Tucker**, STR **Samuel Demtsu,** NREL **Russ Hewett,** NREL
2:45–2:55 p.m.	***……. Break …….***
2:55–3:55 p.m.	***Central State University, Mr. Clark Fuller, Principal Investigator*** ***The Central State University Renewable Energy Research Associates Program – An Overview***

Clark Fuller, Central State University

Summer 2004 Internship at Texas Southern University Photovoltaic Laboratory (REEP Program)
Carl Eloi, Central State University

Power Storage for Refrigerant Reefer Trailer
Andrew Grissom, Central State University

Photovoltaic System Integration For Refrigerant Reefer Trailer
Shannon Adonis Jones, Central State University

3:55 p.m.	***……. Break/ Travel back to hotel …….***
4:45-6:00 p.m.	***Oral and Poster Final Judges Meeting***
6:30–8:00 p.m.	**REAP Awards Dinner – *VSEC Visitor's Center***

Moderators: **Jamal Thompson,** Howard University
Syl Morgan Smith, NREL

Awards Presentation – **Fannie Posey Eddy**, NREL
Syl Morgan-Smith, NREL

Response from REAP Participants

***Introduction of Keynote Speaker*:** **Jamal Thompson**, Howard University

Keynote Address: **Marvin Gunn, U.S. Department of Energy, Chicago**

Friday, August 13, 2004
FSEC Auditorium

8:00-8:30 a.m.	***Continental Breakfast***
8:30-12:30 p.m.	***Technical Presentations and Poster Session***
	Moderator: **Ms. Jauna Ameiva,** University of Texas at Brownsville MURA Research Associate
8:30–8:45 a.m.	***Progress in Nanotechnology Research at North Carolina Central University*** B. Vlahovic, North Carolina Central University
8:45 –9:45 a.m.	***Clark Atlanta University, Dr. Randal Mandock, PI***
9:45–9:55 a.m.	***…..Break……***
9:55-10:10 a.m.	***Interaction of Government, Industry and Academia in Support of Solar Energy Deployment*** **Abayomi Ajayi-Majebi,** PhD, PE, Central State University

10:10-10:25 a.m.	***Svannah State University, Dr. Alex Kalu, Principal Investigator***
10:25-10:30 a.m.	***……. Break …..***
10:30-12:30 p.m.	***FSEC Short Course for Students***
12:30–2:00 p.m.	***Lunch with Speaker – FSEC Visitor's Center***
	Moderator: Kenyatta Williams, MURA Research Associate
	Guest Speaker - Tamara Jackson, US Senate Technology and Commerce Office
2:00 p.m.	***……. Adjourn …….***

Saturday, August 14, 2004

9:30–10:30 a.m.	**PI Breakfast Meeting at hotel - Conference closeout**
10:30–11:00 a.m.	**Check out of hotel**

Conference Description

Program Overview

The DOE-NREL Minority University Research Associates Program (MURA) is an undergraduate research program that encourages minority students to pursue careers in science and technology. In this program undergraduate/graduate students perform renewable energy research projects during the academic year with principal investigators at their university and are awarded summer internships in industry or at national laboratories like NREL during the summer. Once accepted into the program students can work on a research project for 1-3 years. By providing renewable energy research opportunities, the program has proven to be very successful in retention of minority undergraduate students in the science and technology areas and helping many students reach their educational and career goals.

Because of this program's successes, the program has been expanded to include additional minority-serving colleges and universities and all solar energy technologies. Each university will conduct research in 1-3 areas: Basic Research, Photovoltaic Panel Measurement and Testing and Solar Radiation Profile Study. This expansion will include Tribal Colleges-Universities, Hispanic, Alaska Native and Hawaiian Native serving college and university students to be included along with the Historically Black Colleges and Universities. Expansion to other solar energy technologies such as wind, bio-energy and geothermal, will provide additional solar energy project opportunities and internships. Students involved in research excel in the classroom learning experience and are committed to contribute to the development of renewable energy technologies in order to create a sustainable environment.

In the past six years the program has sponsored 70 undergraduate students' participation in research projects. In addition, more than 13,000 high school, middle school and elementary school students have benefited from renewable energy camps and summer academies. These activities have produced many research accomplishments and success stories. Several of our students have gone on to graduate school to master their skills in fields such as physics, chemistry, architecture and engineering. Others are now working in industry and government labs, using the knowledge and expertise they have gained as DOE-NREL Research Associates.

The impacts of this program in local and international communities occurred through student-managed community education projects, solar energy workshops and installations in South Africa, Senegal and even on the NREL campus. Each HBCU Team had different research projects and accomplishments. Perhaps the most valuable accomplishment has been the students' motivation to excel in their scientific quest for knowledge and to share their excitement of renewable energy with their local and international communities.

For 10 weeks during the summer students are given the opportunity to work with laboratory scientists and engineers as members of research teams at NREL or at another DOE national laboratory, university or industry partner. The program is intended to provide additional training and skill development needed to prepare students with the necessary education and experience that will enable them to pursue science and technology careers in the renewable energy fields.

At the close of the summer internship program Advisors, students and NREL professionals participate in an annual Renewable Energy Academic Partnership (REAP) review meeting and conference to discuss and share their research papers, future opportunities and the national and global role of renewable energy in ensuring a secure and sustainable environment.

The symposium will focus on NREL/DOE-funded projects at eight minority serving colleges and universities, including Southern University and A&M College, Central State, Fisk University, Howard University, North Carolina A&T State University, North Carolina Central University, University of Texas, Brownsville, and University of Texas, El Paso. Additionally, physics and engineering majors from Savannah State University and Clark Atlanta University will also give presentations.

During the review of progress made on funded projects at each institution, undergraduates, advisors, and experts will have an opportunity to gather and discuss their research and future opportunities in the field of renewable energy. These review presentations will also provide valuable information about the role of renewable energy nationally and globally.

History

In 1995, the U.S. Department of Energy's (DOE) National Photovoltaics (PV) Program at the National Renewable Energy Laboratory, (NREL) in Golden, Colorado, funded nine Historically Black Colleges and Universities (HBCUs) for a period of three years, in an HBCU Photovoltaic Research Associates Program. The purpose of the program was to advance HBCU undergraduate knowledge of Photovoltaics, primarily through research investigations performed, and to encourage students to pursue careers in photovoltaics.

The universities selected were:

Southern University and A&M
Central State
Clark Atlanta
Hampton
Howard
Mississippi Valley State
North Carolina Central
Texas Southern University
Wilberforce University

Last Year

The DOE/NREL Renewable Energy Academic Partnership (REAP) Conference, which was established to review progress on the DOE/NREL funded projects at the nine HBCUs, was hosted by Arizona State University, Tempe, Arizona, in August 2003. The symposium focused on NREL/DOE-funded projects at the historically black colleges including progress made on funded projects as well as discussions about future opportunities in renewable energy.

This Year

The conference and review meeting is being hosted at the Florida Solar Energy Center (FSEC) in Cocoa, Florida. Attendees will share their presentations, tour FSEC's research facilities, and attend solar technology workshops. To further enrich their knowledge, professional and program development workshops are included. One workshop will focus on strengthening minority serving institutions and preparing students to excel in science and technology. In another workshop, we have energy professionals from NREL and our industry partners to talk about their professional life and work in the energy field. Finally, students will attend a short course on "Photovoltaics and Fuel Cells" taught by FSEC faculty.

CARET

Rita Foreman, Director

CARET works to promote educational opportunities in science and engineering for minority students through projects in renewable energy and sustainable development.

CARET is a partnership between minority universities, NASA, and OAI; dedicated to providing students with unique educational experiences in science through projects in renewable energy. This focus has created expertise in several areas of renewable energy; including numerous advanced research topics, technical design, sustainable development, and community outreach and education.

To learn more about CARET and their description for the REAP Program, please visit their website at: www.caret.org

Guest Speaker

Marvin E. Gunn, Jr., Manager

U.S. Department of Energy, Chicago Operations Office

Marvin E. Gunn, Jr. is a career public servant who has focused for almost 30 years on the challenge of achieving excellence in the management of high-technology programs, projects, and organizations. He combines an engineering background, experience in both the public and private sector, and a focus on managerial excellence in terms of leadership, commitment, and performance. He has played key roles in the U.S. Department of Energy (DOE) and its predecessor agencies in both technical and administrative management assignments, and has served in leadership positions on diverse management initiatives, both in and out of government. His unique technical, managerial, and human relations skills have resulted in requests that he represent the United States in international negotiations and collaborations on energy technology development and implementation. He is a frequent speaker before diverse forums on technology, management, education, and technology transfer.

In his current assignment as Manager of the U. S. Department of Energy's (DOE) Chicago Operations Office, Mr. Gunn is responsible for approximately $2.1 billion in research and development, about ten percent of the DOE budget. His responsibilities encompass the integration of program implementation, operations, and administrative management to successfully fulfill the department's varied research and energy technology missions.

In this key role, Mr. Gunn directs the activities of 400 Federal employees and more than 9,500 contractor employees, and his organization administers a host of research and energy technology development contracts throughout the United States. In addition, he is responsible for oversight of cutting-edge, contractor-operated research facilities: Ames Laboratory, Ames, Iowa; Argonne National Laboratory, with sites near Chicago, Illinois, and Idaho Falls, Idaho; Brookhaven National Laboratory, Upton, New York; Fermi National Accelerator Laboratory near Batavia, Illinois; and Princeton Plasma Physics Laboratory, Princeton, New Jersey.

In addition to the above contractor-operated laboratories, Mr. Gunn is also responsible for two government-owned and operated laboratories. New Brunswick Laboratory is a special nuclear materials measurements and safeguards facility located on the Argonne site in Illinois. A second federal laboratory, Environmental Measurements Laboratory (EML) in New York City, which has supported DOE's Environmental Management program, will be transferred to the new Department of Homeland Security on

March 9, 2003. Mr. Gunn's organization will continue to provide support to EML during its transition to the new department.

Mr. Gunn was appointed Manager of Chicago Operations Office in December 2000 and served as Deputy Manager since April 1999. Prior to his appointment to Chicago, Mr. Gunn was Director of the Office of Management and Operations in DOE's Office of Energy Efficiency and Renewable Energy since December 1994. As corporate resource manager for the office, he was responsible for the management of human resources, budget execution and finance, information technology and systems, and field facilities. He also provided corporate oversight for environment, safety and health. From December 1992 to December 1994 Mr. Gunn served as the Director of the Office of Energy Management in the Office of Utility Technologies, managing the development of such technology areas as high-temperature superconductivity, hydrogen R&D, and energy storage.

In a previous assignment, he was responsible for developing and maintaining an enabling technology base in support of industry's effort to improve energy efficiency and enhance fuel flexibility. Since June 1973, Mr. Gunn has held several positions with the department and its predecessor agencies in the areas of nuclear, fossil, and energy efficiency and renewable programs. He has also been a delegate to the International Energy Agency, where he served in leadership positions in both negotiation and implementation of international technology agreements in two assignments totaling more than 14 years.

Mr. Gunn's span of departmental involvements and professional experience has resulted in his service on a number of advisory bodies. Examples include his service on the Laboratory Operations Board of the Secretary's Energy Advisory Board as a non-voting Internal Member providing his insights on issues, challenges, and opportunities affecting the DOE National Laboratories. He has also served for several years as an Advisory Board member of the North Carolina Agricultural and Technical University's Center for Energy Research and Technology, where he advised on research, education, and technology transfer issues.

Among the many awards and recognitions received over his career, in 1997 Mr. Gunn received the Secretary's Gold Award for his participation on the DOE/National Treasury Employees Union Partnership Council. In 1992 he was presented the DOE Meritorious Service Award in recognition of his outstanding contributions to developing a national electric and magnetic fields research and communications program and to the mission of the department. In 1989, he was named Senior Engineer of the Year by the District of Columbia Council of Engineering and Architectural Societies. He holds a Bachelor's Degree in mechanical engineering from Howard University and has completed graduate studies in mechanical engineering and nuclear engineering at Howard University.

Guest Speaker

Frank Stewart, Jr.
Chairman of the Board of Directors, Strategic Environment Project Pipeline (StEPP)
Golden, Colorado

Frank M. Stewart, Jr. is the Chairman of the Board of Directors for the Strategic Environment Project Pipeline, (StEPP). (www.steppfoundation.org). He is also the former Manager of the U.S. Department of Energy (DOE) Golden Field Office. The office is responsible for promoting the development and commercialization of energy efficiency and renewable energy technologies by working with industry, for administering the management and operations contract for the National Renewable Energy Laboratory, and for providing administrative support to DOE's six Regional Support Offices.

Earlier, Mr. Stewart served as Deputy Assistant Secretary, Office of Technical and Financial Assistance, Office of Energy Efficiency and Renewable Energy, DOE. He directed grant programs and provided technical assistance for states and localities, including the Institutional Conservation Program, Weatherization Assistance Program, State Energy Conservation Program, Inventions and Innovation Program, and the Technical Assistance and International Market Support Activities for the Office of Energy Efficiency and Renewable Energy. He served there from 1990 until 1994. Mr. Stewart also served for a time as Acting Assistant Secretary of the Office of Energy Efficiency and Renewable Energy.

Mr. Stewart served as Associated Assistant Administrator for State Assistance Programs in the Federal Energy Administration (FEA), one of DOE's predecessor agencies, until DOE's formation in 1977.

Prior to the FEA assignment, he was with the Department of Health, Education and Welfare as the Assistant Executive Secretary for Education and Civil Rights (1975-1977). From 1966 to 1971, Mr. Stewart held teaching and administrative positions at Rutgers University and at Wesleyan University, Middletown, Connecticut. From 1963 to 1966, he taught school in East Orange, New Jersey.

In 1987, Mr. Stewart was the recipient of the annual Appreciation Award from the National Association of State Energy Officials. At the 1988 World Energy Engineering Congress, Mr.

Stewart was named the Energy Executive of the Year. In 1994, the North Carolina A&T University School of Engineering honored him for his support of the school. He is also the recipient of the Department of Energy's Award for Exceptional Service and the Secretary of Energy's Gold Medal for Outstanding Leadership. Presently, he serves on a number of local, state, national and international advisory groups. He is listed in Who's Who in America and Who's Who in Science and Engineering.

In 1988, Mr. Stewart led the U.S. delegation to the University of Rome's World Conference on Energy Efficiency. In 1994 and 1995, he headed the U.S. technical delegations to Cote d'Ivoire, Botswana, and Ghana. Very recently he served as a member of Secretary O'Leary's historic missions to India and South Africa. From June 1994 until July 1995, Mr. Stewart was the principal energy staff person for the United States/South Africa Binational Commission. In 1996, he led the U.S. delegation that concluded the first Memorandum of Agreement between the United States and the nation of Uganda.

He received his bachelors and masters degrees from Wesleyan University in 1961 and 1963, respectively. He has done additional work at Harvard University and American University.

Guest Speaker

Steve Grey
Director for Indian Affairs Intergovernmental and External Affairs, Office of Congressional and Intergovernmental Affairs, U.S. Department of Energy

Mr. Steve Grey is originally from Kayenta, Arizona. He was born and raised in Kayenta, which is located in Northeastern Arizona on the Navajo Nation. He is currently serving as the Department of Energy Director for Indian Affairs in Washington, DC. Mr. Grey is chairman for the Navajo Nation Telecommunication Regulatory Commission. He also serves on the Federal Communication Commissions Advisory Committee. Mr. Grey is employed with the Department of Energy's Lawrence Livermore National Laboratory. He oversees Lawrence Livermore National Laboratory American Indian Program and manages the Department of Energy Field office, which is located in Shiprock, Navajo Nation, New Mexico.

Mr. Grey graduated from Monument Valley high school in Kayenta, Arizona. He then attended Northern Arizona University College of Engineering where he received his Bachelor of Science degree in mechanical engineering. Mr. Grey also received his Master of Business Administration degree (MBA). Mr. Grey resides both in Farmington New Mexico and on the Navajo Nation. Mr. Grey spends time on and off the Navajo reservation when he is not traveling to California or Washington, DC.

As the Director for Indian Affairs Mr. Grey is the tribal liaison on Indian Issues for the Department of Energy within the office of Congressional and Intergovernmental Affairs. His primary DOE responsibilities include implementing the Department of Energy Indian Policy and working with all 556 federally recognized tribes. As Program Manager of the Laboratory's American Indian Program (AIP), he manages a Secretary of Energy Initiative, specifically, the Department of Energy (DOE) LLNL Field Office located on Dine' College (DC) grounds in Shiprock, New Mexico. On behalf of DOE the incumbent administers programs impacting American Indians on a national level, which includes interpreting complex and sensitive DOE American Indian policy. As the Program Manager for the Laboratory's AIP he provides leadership for growth, development and participation of American Indians in support of the National Laboratory and DOE's mission to support the American Indian policy and enhance science, technology and research initiatives. The intended impact of this dual national program is to effect technological and educational development and opportunity for American Indians, internal to the DOE National Laboratory's and on a national level. The National Laboratory's maintain cutting edge technology in support of the country national defense efforts. Lawrence Livermore National Laboratory has approximately 8,000 scientist, engineers and support personnel at its California facility.

Guest Speaker

Ryan T. Tucker
STRUS, Inc.

RYAN T. TUCKER is a Polymer Scientist at Specialized Technology Resources, Inc., in Enfield, CT. At STR, he leads the research and development efforts of polymer-based materials for photovoltaic encapsulant and packaging applications and is an internal consultant for STR's extrusion manufacturing facilities worldwide. The author or coauthor of 11 professional papers and book chapters, he is a GEM fellow, a member of the American Chemical Society and National Organization for the Professional Advancement of Black Chemists and Chemical Engineers, and a member and past Vice Chair of the National Society of Black Engineers. A 3M Scholar and recipient of the National Engineering Award, Dr. Tucker received a B.S. degree (1995) in chemical engineering from Northwestern University in Evanston, IL, and a Ph.D. degree (2000) in the Polymer Program from the University of Connecticut – Storrs.

Guest Speaker

Joyce H. Lattimore
Renewable Energy and Environmental Protection (REEP)
Texas Southern University

Joyce H. Lattimore is the coordinator of the Renewable Energy and Environmental Protection (REEP) Program, College of Science and Technology, Texas Southern University, Houston, Texas. REEP includes a summer academy for high school students are invited to become a part of tomorrow's energy solutions today, learn about renewable energy and environmental studies and explore career opportunities in engineering, science and technology. Additionally, Mrs. Lattimore coordinates and supervises student projects and activities of the Photovoltaic Research and Demonstration Laboratory, which is used by the REEP Academy. The National Renewable Energy Laboratory is a major funding resource for the college student projects and activities.

As a recruiter for the College of Science and Technology, she attends career fairs, visit schools, churches, organizations and represents at conferences, seminars and workshop.

Mrs. Lattimore is a graduate of North Carolina Central University, Durham, North Carolina with a Bachelor of Science Degree in Commerce and post-graduate studies at East Carolina University, Greenville, North Carolina and Texas Southern University, Houston, Texas.

She is married to Henry C. Lattimore and there are the proud parents of one child, Alexia L. Moore and the proud grandparents of two grandsons, (Jemal and Jalen). She and the family are members of the Walls Chapel African Methodist Episcopal Zion Church, Houston, Texas.

Central State University

“Renewable Energy Research Associates Program”

Dr. Clark Fuller, Principal Investigator
Central State University

I. BACKGROUND

While under the sponsorship of the DOE-NREL Historically Black College and University Photovoltaic Research Associates Program (1998-2003), undergraduate students at Central State University have learned the basics of wind and solar technology and have focused on research in ways in which photovoltaics can provide new and supplemental energy sources to address the critical shortage of water in many developing countries.

Recently, CSU student research associates have been exploring ways in which renewable energy technologies can be applied to the various modes of transportation. Through a program entitled, “The Summer Transportation Institute”, student research associates have sought ways in which renewable energy technology can be applied towards transportation management, transportation safety, transportation technology, and others. The content of this statement of work focuses on continuing student research in economic development for developing countries as well as new research topics in the various fields of transportation.

2.0 OBJECTIVE

The major objective of this program is to design and implement a renewable energy program for 1-2 Central State University students (research associates) to participate for three years in a basic research program that is designed to introduce the students to the practical application of renewable energy technology in the fields of (a) economic development, and (b.) transportation (various modes). The three-year program is divided into two parallel and mutually supporting components: (1) Renewable Energy Technology for Economic Development; and (2) Energy Applications in Transportation.

3.0 SCOPE OF WORK

Work is performed in two areas: (1) Renewable Energy Technology for Economic Development; and (2) Energy Applications in Transportation. The program is directed and administered by a Principal Investigator (Mr. Clark Fuller, Associate Director, Office of Sponsored Programs & Research). 1-2 students (and possibly others) have been identified to participate in the program.

3.1 Renewable Energy Technology for Economic Development

Objective

The research and course work conducted by students in this component of the program are given a broader understanding of how renewable energy in general, and photovoltaics in particular, can assist Third World countries in development efforts. It also provides a field laboratory where students can practically apply concepts and principles from the classroom and local research to a real-world environment with real-world challenges. Unlike the boredom and repetition of traditional classroom study, this unique program will, in the end, provide the exposure to a field of energy that will encourage them to pursue additional studies, employment and careers in photovoltaics.

3.2 *Renewable Energy Applications in Transportation*

Objective

The research associates are required to perform design and problem solving tasks in order to complete working transportation models powered by renewable energy. While under the guidance and leadership of professors within the Department of Manufacturing Engineering and Water Resources Management, students perform up to 20 hours per week on research projects that have a transportation theme.

Further, as part of a collaborative partnership arrangement between Central State University, the NASA Glenn Research Center and the Ohio Division of the Federal Highway Administration, the Office of Sponsored Research combines and expands its Renewable Energy Research Program to include student research projects as they apply to the various fields of transportation. The exploratory research projects include a feasibility studies (with guidance from the Ohio Department of Transportation) regarding solar lighting and heating for bus stops; a design plan for solar lighting along CSU's Tawawa Apartments walkway; and, the design and construction of a solar charging station for CSU's electric carts (used in materials management).

The outcome of the projects as described above are integrated into a four-week summer transportation institute for high school students (June/July each year) that includes a week-long exposure to renewable energy technology and applications.

"INTERACTION OF GOVERNMENT, INDUSTRY AND ACADEMIA IN SUPPORT OF SOLAR ENERGY DEPLOYMENT"

Abayomi Ajayi-Majebi, PhD, PE
Professor, Manufacturing Engineering Dept.
Central State University

The generally acceptable fact that solar energy and power represents an abundant, reliable, sustainable, clean, resource conserving and low maintenance alternative to conventional fossil energy supply is driving a lot of actions in the economic system to create, sustain awareness of and increase the deployment of this energy source. Furthermore, since solar energy can serve as a clean back-up power that can be generated right at the source, with no noise pollution, mechanical frictional losses, fuel consumption or moving parts, it represents a technology that will continue to occupy an important niche in the current effort to create viable energy choices for the masses and a reliable source to meet future energy needs. Presentation is made of the research work that highlights the successes of government, the industry, and academia to create awareness in the global community, of energy opportunities, issues and concerns supported by recommended actions that promise to prevent future energy shortage problems. Specifically the research work done in: 1) studying the feasibility of deploying solar energy on semi-articulated truck trailers, and 2) studying the Tawawa Walkway Lighting research project in Wilberforce, Ohio is presented. Current work in progress in collaboration with SuperDrive Inc. in studying the feasibility of implementing solar energy systems on board the trailers of trucks to provide a primary or auxiliary solar system to power such components as the refrigeration unit of a truck trailer is presented. At another level, the incentives provided by the state and federal governments in support of the industry regarding solar energy technology infusion into the economic system is presented including such developments and incentives in force in the State of California. The solar energy research study reported is supported jointly by the National Renewable Energy Laboratory in Golden, Colorado and also by a high technology innovation company, SuperDrive Inc. in Piqua, Ohio. The progress made so far is presented, future opportunities, directions and challenges are highlighted.

SUMMER 2004 INTERNSHIP AT TEXAS SOUTHERN UNIVERSITY PHOTOVOLTAIC LABORATORY & REAP PROGRAM

Carl Eloi
Central State University/Texas Southern University

This summer internship at Texas Southern University was made possible with a collaborative effort between advisors of Central State University, Texas Southern University and the National Renewable Energy laboratory (NREL). I will be working at an established Photovoltaic laboratory at Texas Southern University where I will be joined by Tony Prince a graduate of Texas Southern University, Samuel Adderley a student form the College of Bahamas, and Garson Myles a student at Texas Southern University. We will have to create projects based off previous research work done in the laboratory. As an example we will be charged with creating a photovoltaic system at an undisclosed site and also set up test for the battery free refrigerators in the laboratory. Another objective is to keep the 4-kilowatt system at the photovoltaic laboratory working at the required specification.

The other half of the internship is a two-week period where I will be the chaperone of four high school students involved in the (REEP) program. I will also be charged with assisting (REEP) staff members in achieving goals and objectives related to educating the young minds on the importance of harnessing the sun's abundant energy. Another task involves participating in educational activities such as photovoltaic module exercises, and domestic and international field exercises. I will be seeking creative solutions for energy conservation and environmental protection along with the (REEP) program students and my respected staff associates.

Power Storage for Refrigerant Reefer Trailer

Andrew Grissom
Central State University

There are many concepts and ideas when it comes to renewable energy. Out of these ideas the most commonly thought of is solar energy. The ideas here are to capture the solar energy incident on the top and possibly sides of a reefer trailer of a semi-truck and perform a controlled release of the stored solar energy to augment the fossil fuel energy delivered to the motor which is used to run a compressor for the refrigerant system on the trailer. This idea or strategy would reduce the amount of fossil fuel energy currently consumed by the refrigerant motor thereby providing energy savings to the trucking industry and the truck operator. More explicitly, numerous advantages of this scheme exist such as increased fuel mileage, no pollution to the environment and less strain on the limited and relatively expensive sources of the current fossil energy supply that is steadily being depleted. By generating a specific amount of energy using solar cells and releasing this through a D.C. power supply, it is possible to power the refrigeration unit to operate on its own for a certain or set amount of time.

Photovoltaic System Integration For Refrigerant Reefer Trailer

Shannon Adonis Jones
Central State University

This Renewable Energy Research Project has as a main objective, provision of a framework for integrating the components of a solar energy system to deliver energy that will reduce the work of the motor powering the refrigerant unit on the reefer of a semi-trailer. Effectively, the solar energy storage and delivery system will be used to operate the trailer cooling system. The trailer of a semi-truck contains its own motor sometimes powered by diesel fuel. These trailers are known as reefers. The motor provides power to the refrigerant unit, which refrigerates and keeps cool transported items or other items that need to be cool. There are times when truck drivers have to deliver cooled products to different stores. A lot of times the products have to sit out and run the risk of spoilage over an extended period of time after they have been delivered. The motor operates the refrigerant unit, so that it is able to keep the products cool without the truck being attached to it. The main purpose of this project is to install a solar energy system on the top and possibly the sides of the trailer so that it will assist the motor in operating the refrigerant unit thereby consuming less fossil fuel. Within this presentation five major components will be used and described: solar panels, DC Power supplier, motor, battery, compressor and control device system. How these components are integrated in a functional system is presented to enhance the cooling sufficiency of the refrigeration system.

Stability of Thin Film CdS/CdTe Solar Cells

Samuel Demtsu
Department of Physics, Colorado State University, Fort Collins, Co 80523

In long-term stability tests cells are exposed to elevated temperature, illumination and electrical bias. Stability of CdS/CdTe solar cells is generally associated with metal diffusion, typically copper, from the back contact of the cell. However, cell fabrication processes can also affect stability of CdTe based solar cells. Several causes have been proposed to explain cell degradation, such as primary junction degradation, degradation of the electrical contact, and shunting. Degradation is manifested as a decrease in open-circuit voltage (Voc), increase in series resistance (Rs) and decrease in fill factor (FF). Different modes of degradation that affect cell performance are discussed.

*I am a PhD student at Colorado State University working several days a week at National Renewable Energy Laboratory (NREL) on a joint project.

Development of Quantum Dot-Sensitized ZnO and TiO_2 Nanorod Array Solar Cells

D. Jowhar, D. O'berry, E. Ojomo, I. Adebiyi, O. Ajiboye, A. Ueda and R. Mu*
Nano-VP Program, Nanoscale materials and Sensors lab
Department of Physics
Fisk University, Nashville, TN 37208

The study has shown that quantum dot based optoelectronic devices can benefit from two distinct and unique features different from its bulk counterparts. One is the enhancement of the optical oscillator strength and the other is the tunability of the optical bandgap. Both properties are originated from the quantum confinement effect of the photon generated charge carriers inside the semiconductor nanocrystals when the exciton Bohr radius of the semiconductor is comparable or larger than the actual physical size of the nanocrystals. In the case of photon energy conversion, quantum dot based solar cells can provide two fundamental ways to utilize the hot carriers by an enhanced photovoltage or an enhanced photocurrent. [1] The former requires that the charge carriers be extracted before they cool and the latter requires the hot carriers to produce more electron-hole pairs through impact ionization (that is an inversed Auger process). The maximum conversion efficiency can be raised from 32% for conventional device to 66% for quantum dot solar cells that make the full use of hot carriers.[2]

The final solar cell structure is based on a modified version of the *Gratzel* cell. [3] As illustrated in figure 1, there are three major modifications to be carried out: 1) the sintered nanocrystalline TiO_2 layer used in *Gratzel* cell will be replaced by TiO_2 or ZnO nanorods with our recently developed nanopatterning technique. The advantage of using nanorods is to minimize or eliminate the grain boundaries that trap the charge carriers without much sacrifice of the total surface area; 2) InP or GaAs quantum dots will be directly deposited on to the nanorod surface by pulsed laser ablation (PLA) to substitute for the dye molecules in *Gratzel* cell since the only quantum dots (not dye molecules) are able to have inversed Auger process to occur; [1,2] and 3) a hole-conducting polymer – MEH-PPV

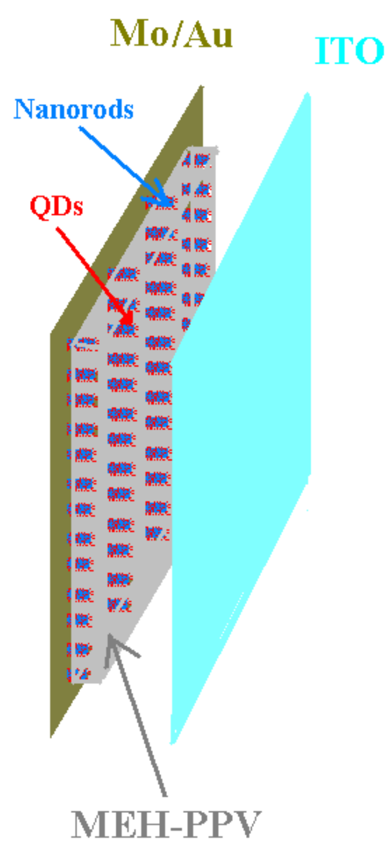

Figure 1. Proposed quantum dot solar cell structure. (color code indicates the materials used.

is used as the matrix of the cell. Indium tin oxide (ITO) and Mo/Au are used as the electrodes on both sides respectively.

In order to achieve our final goal of developing the final solar cells, the Nano-PV team have initiated six small projects by targeting two major challenges: 1) Materials Development (MD) and 2) Technology Development (TD). In the MD front, there are five students working on five potential materials. They are: TiO_2 and ZnO to be used as nanorods electrodes, Indium Tin Oxide (ITO), Gold (Au) and Aluminum (Al) for conducting layers, and functional polymer for potential substrate materials. In the TD front, we have started to fabricate quantum dots with pulsed laser deposition technique. The research in MD, all five students will present their results. The focus here is on TD progress.

Fabrication of Silicon Quantum Dots as a Srototype System

Pulsed laser deposition experiments were performed with the output from a frequency tripled 30 ps pulse width Nd:YAG laser. The target, an undoped <111> Si wafer, and the substrate are contained in a vacuum chamber with a base pressure of 1 x 10^{-7} torr. The target was attached to a rotating mount to decrease the effects of surface texturing from repeated laser shots. Freshly cleaved mica was used as the substrates for samples studied with atomic force microscopy (AFM), while fused silica (SiO_2) was used for samples studied by optical absorption. Target to substrate distance was maintained at 4 cm. The laser beam was focused by a 50 cm focal length lens onto the target, with a spot size of approximately 0.5 mm^2. Samples used for optical absorption experiments were multiplayer samples fabricated by depositing a layer of nanocrystals on a substrate, then using electron beam evaporation to overcoat the substrate. The cycle was repeated 5 – 10 times to obtain samples with sufficient optical absorption to achieve good signal to noise ratios. AFM measurements were performed with a DI Nanoscope III in tapping mode to avoid displacement of the nanoparticles. Particle sizes were obtained by using a 2D peak finding computer program to analyze digitized height mode images from the Nanoscope. AFM samples were made with low shot numbers so individual particles could be clearly resolved and to avoid stacking particles.

The research focus here is on repeatable production of high quality silicon quantum dots with narrow size distributions. Silicon nanocrystals are predicted to have bandgaps that span the visible region of the spectrum. We have employed picosecond pulsed laser ablation to fabricate nanocrystals with diameters ranging from one to five nanometers. Picosecond pulses were used to minimize thermal effects that can lead to production of extremely large (>

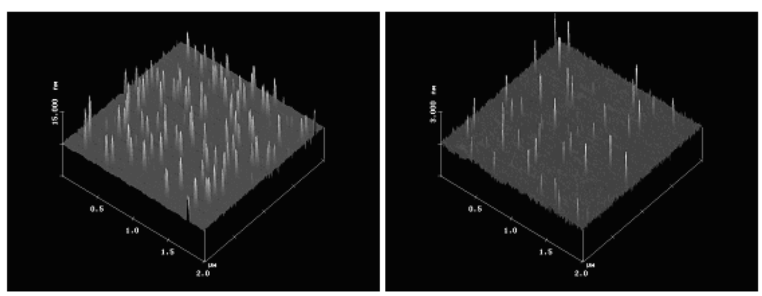

Figure 2 Height mode AFM images of Si nanoparticles produced

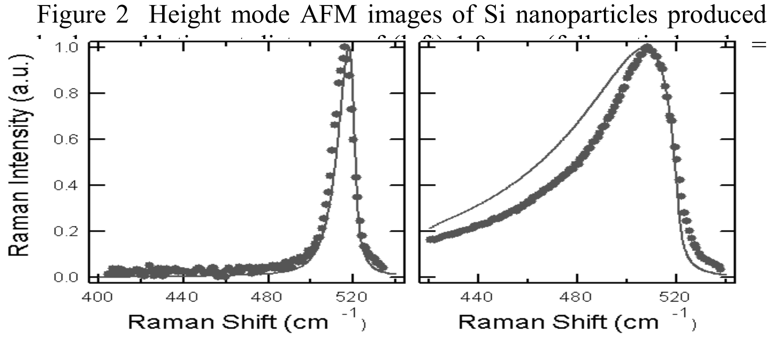

Figure 3. Normalized micro raman scattering spectra of silicon nanocrystals near regions imaged by AFM in Figure 2. Circles are experimental data; lines are spectra calculated from theory.

20 nm) nanocrystals due to splashing of melted silicon from the target. Size of the nanocrystals can be controlled by variation of the laser pulse energy, inert backing gas pressure and collection distance from the plume center. Careful optimization of the first two parameters leads to production of nanocrystals with the proper size range. Sampling the collection substrate at increasing lateral distances from the plume center (the third parameter mentioned above) then reveals nanocrystals with decreasing diameters. This is illustrated by atomic force microscope images shown in figure 2.

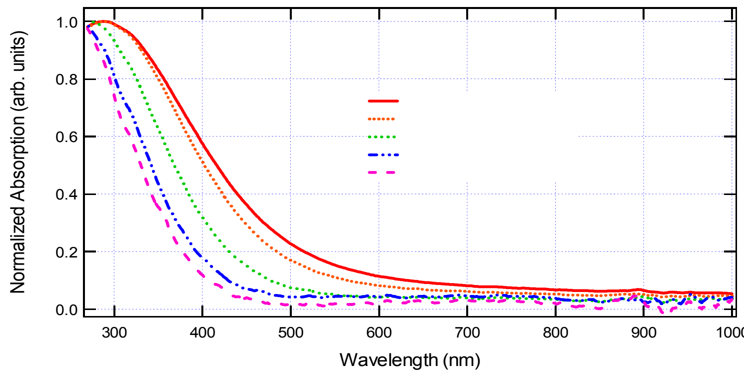

Figure 4. Optical absorption spectrum of silicon nanocrystals.

Nanocrystals have relatively narrow size distributions, with standard deviations roughly 10% of the average size for 5 nm nanocrystals. The morphology of the nanocrystals can be confirmed by Raman scattering spectroscopy. Raman scattering peaks due to the transverse optical phonons of the silicon lattice broaden and shift in frequency as a consequence of confinement to nanometer dimensions. Experimental data, combined with theoretical predictions are shown in figure 3.

Optical absorption spectra of a sample composed of multiple layers of silicon nanocrystals deposited in SiO_2 is shown in Figure 4. The measured bandgaps vary from 480 nm to 700 nm, providing coverage of much of the solar spectrum.

We have thus successfully demonstrated production of silicon nanocrystals with optical bandgaps that are appropriate for advanced solar cells. Several issues remain to be addressed, however, before quantum dot solar cells can be deployed. Mechanisms of carrier separation and transport in layers of closely packed quantum dots and detailed device design considerations (substrate, window choice), for example, can be investigated now that nanocrystal samples are readily available. We are also currently using our laser ablation expertise to produce other types of nanocrystalline materials, such as InP and GaAs, that may be used in quantum dot solar cells.

Nanorods Fabrication with Nanosphere Patterning

Success has been achieved recently using micron and submicron silica spheres to fabricate 2D particle arrays on Mica and glass substrates. The 2D assembly is 1-5 mm in size depending on the deposition conditions, sphere quality and type of substrate. Figure 4 is a sample AFM image of a 2D colloidal crystal formed from 1.06 □m silica microspheres. Clearly, the structure is closely packed. There are structural defects observed which are the result of the imperfection of the microspheres, such

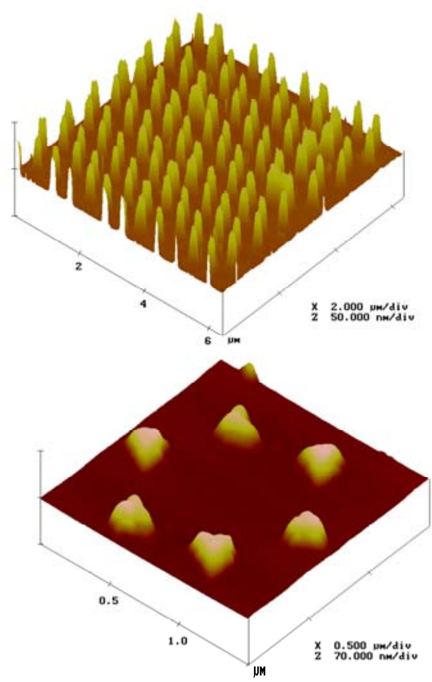

Figure 5. AFM images of 1 micron silica sphere patterned Au nanoparticle arrays. (top) larger view (bot.) Zoomed in view.

as, dimers that were formed during the chemical synthesis or aging process. Using 2D microsphere assemblies as templates, thin (4, 8 and 30 nm) films of Au or Zn have been deposited on the surface. Upon the removal of the microspheres, ordered 2D arrays have been obtained, as illustrated in figure 5. The smallest size of these triangles achievable is ~ 10 nm with an ordered array size on the scale of tens to hundreds of micrometers. More research is currently under way to achieve millimeter scale self-assembly with nano-spheres.

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The Fabrication and Characterization of Indium Tin Oxide and Photovoltaic Cells

Ibrahim Adebiyi, A. Ueda, and R. Mu
Fisk University / University of Oklahoma, Tulsa

As we know, the energy consumed in the world is from fossil fuels, which are expandable and are the major cause of conflicts between countries. Statistics show that fossil fuels will be exhausted in the year 2111. So far, people have found alternative sources of fuel, which is the recovery of energy of the sun that can be used without the fear of being exhausted. The “solar revolution” has been around for 20 years with the production of conventional solar cells but these solar cells only have a ~ 40% theoretical conversion efficiency. It is predicted that the nano-composite cell can increase theoretical efficiency to 66%. In this structure, indium tin oxide will be used as an electrode material for the cell. It is used because of its high optical transparency and high conductivity. In my summer research, I have used an electron beam evaporator to evaporate indium tin oxide on to the silica glass. Indium tin oxide is then placed in a furnace at high temperatures and form a certain period of time under Oxygen and Argon atmosphere. We then use UV-visible and the FTIR spectrometer to measure the optical property change under various conditions and electrical measurements were also conducted in order to obtain the best quality of the ITO film for solar cell development.

Optical Properties of Nanolayerd Polymers

Olabode Ajiboye and A. Ranade
Fisk University

Fabrication of highly functional nanolayered polymer is very attractive in many optical electronic applications. CO extrusion and Nano layering, for example, has proven effective in achieving a partial mixing of polymer as they would not ordinarily mix due to the insufficient change in free energy. These nanolayers consist of thousands of repeated layers of two or three polymers used in the system and they are assembled via co-extrusion to form 1-D photonic crystals. The effect of layer thickness and the nature of the interphase are being investigated. Specifically, it was found that when the layer thickness reduces below the quarter wavelength of incidence radiation, the material exhibits an average refractive index property. Also when the layer thickness is close to the quarter wavelength, it exhibits highly iridescent characteristics. This project is also involved with manipulating this reflective characteristic to achieve reflection of specific wavelength ranges of the light spectrum for numerous reasons. One of the final goals is to explore the potential to apply nanolayer technology to our currently active research in Nano-PV program.

Fabrication and Characterization of TiO_2 Nanorods for Nanocomposite Solar Cells

Dawit Jowhar, D. O'berry, E. Ojomo, I. Adebiyi, O. Ajiboye, A. Ueda, and R. Mu
Fisk University

The earth's natural resources have been depleting by rising energy needs. The sun has been proven to be an inexhaustible resource. If properly harnessed, it would more than satisfy the needs of humanity. Conventional solar cells that are being implemented currently have a theoretical efficiency of 40%. This efficiency can be increased by using nanocomposite solar cells. The predicted efficiency is going to be 66%. The use of quantum dots on the nanorods helps to collect broader wavelengths of photons, thereby enhancing the conversion efficiency of the solar cells. TiO2 has been chosen as a suitable nanorod material in a photovoltaic cell. It is a wide band gap semiconductor which facilitates the transport of electrons and is easily available. Several thicknesses of TiO2 were deposited on silica using e-beam evaporation. Thermal treatments were applied at various temperatures and annealing time. UV-VIS and FTIR spectra were collected and some experimental analysis has been done. In my presentation, I will be sharing my experimental results followed by discussion.

Fabrication and Characterization of ZnO Nanostructures for a Novel Solar Cell Development

Dionicia O'Berry, A. Ueda, and R. Mu
Fisk University

Nanotechnology offers promise for renewable energy technologies. On the one hand, the precise control of matter at atomic and molecular level is a requirement for renewables such as cost effective solar cells, which is much cheaper and more lightweight than bulk. Conventional solar cells have a theoretical photoelectrical efficiency of ~ 40%. Predicted efficiency for nanostructures can be up to 66%. This could significantly increase the amount of electricity converted from sunlight by using nanostructured nanostructured active layers by more effective light absorption. Recently, the Nano-PV research team has proposed a new solar cell structure which is based on the photoelectrochemical cell structure by replacing two key components of the cell: 1) using semiconductor quantum dots to replace the conventional dye molecules and 2) employing 1-dimensional nanowires/nanorods to substitute the typical TiO2 nanocomposite electrode. With this structure, it is possible to improve solar cell performance drastically. As a part of team efforts, I have been focused on development of ZnO nanorods structure. In my presentation, I will be presenting some of my work obtained during the summer internship.

Fabrication and Characterization of Gold Thin Film for Nanocomposite PV Devices

E. Ojomo, A. Ueda, and R. Mu.
Nano-PV Project, Nanoscale Materials and Sensors Lab, Department of Physics, Fisk University, Nashville, TN

Solar cells are devices that directly convert solar energy (light energy: photons) into electrical energy. The advantages of solar energy over fossil fuels are tremendous. Solar energy is more environmentally friendly and almost can last forever. The first solar cells that were built had conversion efficiencies less than 1%. Now theoretical conversion efficiencies of solar cells can be around 40%. The main reason the conversion rates of present solar cells is so low is because absorbed photon energy far above the semiconductor band gap is lost as heat. Quantum solar cells, on the other hand, have theoretical efficiencies over 66%. Both Al and Au films will be used as the contact materials for the solar cells due to their good electrical and thermal conductivity properties at high or low temperatures. In my summer research, the gold films have been evaporated on to different substrates, the substrates will be thermally treated at various temperatures and annealing atmosphere. Optical and electrical properties of the substrates will be measured. In my presentation, I will be sharing my experimental results and discussion will be followed.

Esosa Ojomo [eojomo@hotmail.com]

DESIGN AND IMPLEMENTATION OF A PV BASED POWER MANAGEMENT SCHEME

Ayodele Ishola-Salawu
Howard University

Due to the growing concern of problems relating to the environment, fluctuating fossil fuel prices and other system related constraints; non-conventional energy resources such as photovoltaic, wind, biomass, tidal, and geothermal energies are being investigated for the generation of electricity.

In particular, solar energy is a renewable, clean, non-polluting and cheap source of energy. At present, in many parts of the world, Photovoltaics cells (PV) are being considered as a feasible alternative and direct method for generating electricity. The quest for further enhancement in power system technology due to large energy growth and high demand nation wide, limited transmission capacity across the country have prompted the need for different distributed energy resources and assessment of their impact on the overall distribution system.

In this work (design and implementation of a reliable PV based power management scheme), a review of state-of-the-art technology in the widely used renewable energy resources is presented. The mathematical modeling of all the technologies reviewed is also presented. Evaluations of the accuracy of the mathematical models are performed using available computational tools for renewable energy sources. The impact analysis is performed after integrating the various models into the power distribution system. This work also features the experimental work done on the implementation of the scheme with the pre-college students on an outreach program at CESaC, Howard University during the Summer 2004 outreach program for pre-college students. A scheme to intelligently dispatch the power from all the renewable energy sources to the load in the grid system is currently being designed.

DESIGN AND IMPLEMENTATION OF A PV BASED POWER MANAGEMENT SCHEME

Chinedu Onyegbula
Howard University

Due to the growing concern of problems relating to the environment, fluctuating fossil fuel prices and other system related constraints; non-conventional energy resources such as photovoltaic, wind, biomass, tidal, and geothermal energies are being investigated for the generation of electricity.

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Hydrogen Production Through the Use of a System Utilizing High-Concentrator Photovoltaics (HCPV) and Solid Oxide Electrolyzer Cells (SOEC)

Jamal Thompson
Howard University

The use of electrolysis to crack hydrogen from water is one of the most energy intensive hydrogen production processes. However, with O2 as the only byproduct, electrolysis provides a pollution free hydrogen production process. This paper examines a system that uses electricity and heat, generated from high-concentrator photovoltaic cells, to separate hydrogen from water molecules in a solid oxide electrolyzer. A component level cost analysis is conducted on the major system components and used to determine ways to reduce cost. The cost analysis is also used to compare the cost and performance to similar processes (i.e. gas reformation, wind, nuclear, etc.). The performance of the system when provided different solar resources is examined as well. There are many design elements that need to be reviewed for such a system to be manufactured. These elements include the systems package design, thermal management, and efficiency. The goal is to prove the feasibility of using the Sun's free energy to produce hydrogen from water.

North Carolina A&T State University

Summary of Current Energy-related Projects

Ghasem Shahbazi, Professor
NCA&T State University
Greensboro, NC 27411

NC A&T State University has started it MURA project in July 2004. As a result, we will provide a discussion of the on-going energy related projects on NC A&T SU campus.

PV Demonstration Project:
This project will be presented by Miss. Cynthia Prince

Biogas:
A small plug flow anaerobic digester (3'x 20') has been developed, constructed, and tested. This development and test have been carried out at NC A&T SU farm.
When this digester is filled with manure (20% solid content) to 60% of its capacity, it would generate 603 cubic feet of low pressure biogas per day. Once it is compressed to 7.5 PSIG, we would have 2036 liters of compressed biogas. This volume of gas would generate 3.3 kW-hrs of electric power each day which is required by the project.

A 1.1 kW internal combustion engine-generator was tested with simulated biogas. The test set-up included a gas flow meter that was used to measure the real time gas flow (l/m). The flow meter also allowed us to measure the cumulative gas consumption during each test. Based on these measurements the average fuel consumption by this modified engine-generator was measured to be 10.5 and 12.3 liters per minute, at a pressure of 7.5 and 12 PSI, respectively.

Biopolymer:
The growing demand for lactic acid as a resource for biodegradable polylactic acid (PLA) plastics creates a great economic opportunity for the major agricultural byproduct, cheese whey. Fermentation of cheese whey in a laboratory size, spiral-sheet bioreactor is being used to produce lactic acid. Lactic acid is being extracted and purified from fermentation broth through a three-step membrane separation system. Lactic acid of high purity has a high potential for use as monomer to produce a biodegradable polymeric material for use in food processing and transportation industries.
The purified lactic acid will be polymerized by direct catalyst polycondensation into biodegradable polylactic acid in a laboratory-scale vacuum reactor equipped with solvent reflux and temperature control. The polymer will be isolated and purified. A series of polymer characterization procedures will be followed using gel-permeation chromatography (GPC), and differential scanning calorimeter (DSC), thermogravimetric analyzer (TGA), infrared spectroscopy (FT-IR), melt indexer, and capillary melt rheometer. Tensile specimens will be made using compression molding machine and mechanical properties of the polymer will be determined using Instron universal testing frame. The results of this study will be compared with the previous studies on biodegradable polymers to provide insights into the structure-property relationships of high molecular weight polylactic acid derived from this process.

Biomass Resources:
This project presents a methodology for the assessment of available crop residues in North Carolina. The range of utilization options considered includes production of ethanol through fermentation and heat through direct combustion. The analysis consists of the potential for conversion of North Carolina's biomass resources into energy resources on a county- by-county basis. It includes a summary of the total

resource produced, the amount of the biomass resource that is available for energy conversion, and the amount of energy that could be produced in the form of heat or liquid fuel.

The total amount of useable crop residue produced in North Carolina is 1,466,190 dry ton per year. Majority of these residues is left in the field as field cover.

Production of Hydrogen through Fermentation:
Producing hydrogen through bacterial fermentation processes is the most natural and important method of generating hydrogen. We are conducting tests to screen and select the most efficient hydrogen producing bacteria and determine the optimum condition for their metabolic activity. We will enhance these metabolic activities by employing an enrichment method which includes the use of nutrients cystine, Tween 20 and others. By stressing these bacteria with environmental factors such as temperature and nutrient, we can induce new abilities and new characteristics in these microorganisms, which will make them suitable for our desired applications.

Fuel Cell Demonstration Project:
In general, fuel cells operate on the basis of electrochemical process, which was discovered more than 150 years ago. Fuel cells began supplying electric power for spacecraft in the 1960s. Today they are being used to provide on-site power for banks, data processing Centers, and office buildings as well as mobile applications such as automobiles.

A 5 kWe Proton Exchange Membrane (PEM) fuel cell from Plug-Power is installed to supply electric power and hot water to the ROTC building on NC A&T campus. This unit is being monitored for its performance and reliability. A solid polymer ion exchange membrane is being used as an electrolyte. Platinum Ruthenium is being used as the catalyst. It uses a three-stage fuel reformer to convert natural gas into hydrogen. Operating cell temperatures is 180 oF.

North Carolina A&T State University

The Dissemination of Knowledge: Scientific Database

Janie D. McClurkin
North Carolina A&T State University

For many scientists there is a common phobia of database development and database entry. This irrational fear comes from the misconception that there is little or no security over who can access the information stored in the database. Surprisingly, scientists have egos and fear that sharing their knowledge or results from experiments on intra-office web databases will belittle their foundational discoveries. On the contrary, if these professionals would realize that their work could be the basis for complex discoveries, knowing that credit must be given to them, there would be a new comfort with the exchange of ideas and results. Databases available on intra-office websites have the option for co-workers to access them with a proper username and password; this allows for heightened security. Understanding that scientific advances are built on previously tested hypotheses is the first step in being comfortable with database entry. An ideal database would store conclusions from laboratory experiments for the accessibility of others whose intentions are to further a recorded idea. This system-yielding the ability for an open exchange of ideas from professional to professional-is an advantage for the continual development of scientific technology.

North Carolina A&T State University

Solar Photovoltaic Power Generation Demonstration Project
at
NCA&TSU

Cynthia Prince and Dr. Ghasem Shahbazi, NC A&T

This project demonstrates the potential of a photovoltaic system to be an environmentally friendly and renewable source of energy compared to conventional electricity generation. A 2.5 kW photovoltaic (PV) system of thin-film solar modules with battery storage for emergency power supply and electric power use at night, was designed and installed in a 1,200 square foot apartment unit in collaboration with the Greensboro Housing Authority (GHA) to test the ability of a solar powered system to serve as a supplemental source of electricity for the operation and comfort of the unit. The power generation system was interconnected with the local electric utility grid to allow for monitoring of total power use by the unit and to determine the performance of the installed photovoltaic system.

Daily system performance was monitored through a Data Acquisition System (DAS) that tracks weather conditions and the PV system's power output. The data were analyzed to determine the performance of the PV system (e.g., PV generation, battery charge level, and proper control of energy consuming electric loads) and to produce estimates of life-cycle costs and performance of the PV system.

The results show that the system performed at about 89.2% of the performance level projected by a computer simulation model. The optimal performance of the system was likely affected by the average solar radiation for the test period (January, 2003-December, 2003) which was less than the typical average solar radiation in Greensboro. It should be noted that this underperformance is only 10.8% and optimal weather conditions would not have drastically changed the economics of photovoltaic generation.

In addition to testing the installed photovoltaic system, the project serves as a demonstration unit for training students and raising public awareness about the use of solar energy and for studying consumer behavior and interaction with this new technology.

Two primary types of solar cells are available commercially: crystalline silicon and thin film. In thin film technology, the PV material is deposited on glass or thin metal that mechanically supports the cell or module. Where crystalline silicon requires a wafer about 100 microns thick or more, thin film devices are about 1 to 5 microns thick. Thin film cells work according to the same general principles as crystalline silicon cells but they require less material. Thin-film modules are usually produced differently than silicon-cell modules, making them much simpler and less expensive to produce. Since thin film technologies appear to hold the most potential for being produced inexpensively, we decided to test a thin film product especially designed for use as a power source for housing.

This project tests the performance of thin-film amorphous silicon PV modules in generating electrical power for a 1,200 square foot occupied apartment unit. Power generation for the one year period of 2003 was 2927.25 kWh. Based on the one-year data and making life cycle cost projections (assuming a 20-year useful life on equipment), the electricity produced by this system cost approximately $0.29 per kilowatt-hour. This cost is much higher than that charged by the local electric utility, Duke Power (about 8 cents per kWh for residential service). Based on this cost comparison analysis it might be concluded that PV systems like the one tested are not able to generate energy at a price comparable with utility companies.

However, there are a number of ways to make PV generation more cost effective. First, below-average levels of solar radiation were experienced during the test period. A much longer test period is necessary to fully evaluate the energy generation potential of this system.

Second, using a grid-tied photovoltaic inverter we believe can reduce the cost of electricity generation by 4 cents per kWh. The efficiency and cost of the power-conditioning subsystem is a significant factor in the future of photovoltaic system feasibility. Better matching of power conditioners and photovoltaic arrays could reduce the cost of power generation. We believe that a major determining factor responsible for relatively high cost of the electricity generated during the test period can be attributed to the power demands of the power conditioning system and the batteries that comprise the array. In grid-connected PV systems like the one we tested, efficiency can be improved by connecting the system directly to the grid using a grid-tied photovoltaic inverter making the use of batteries unnecessary. There would be additional savings in installation and maintenance of the system since batteries and their subsequent replacements contribute to the high cost of the PV system. This means that using a grid-tied photovoltaic inverter can lower the price of the generated electricity.

Third, a statute passed by the State of North Carolina provides for an expanded tax incentive of 35% of the cost of the renewable energy property constructed, purchased or leased by a taxpayer and placed into service in North Carolina during the taxable year. The credit is subject to various ceilings depending on whether the renewable energy equipment serves nonresidential property or residential property. Residential tax credit is 35% up to a maximum of $10,500. If these tax credits are factored in, then the PV system begins to become an attractive option.

Fourth, our annual maintenance cost was higher than the average cost for a similar system, based on the published data. We spent $1,500 for annual maintenance compared to $400 required in another location. There are several reasons for this difference, including the fact that there is only one trained professional who is licensed to do these kinds of projects in our location. Requirements made by the local utility company also made maintenance more costly.

Finally, user behavior must be taken into account with respect to energy use and cost of energy used. We have carried out a drill to formally train the residents in proper interaction with the PV system. The drill involves turning off the grid power to the house and drawing power from the battery and PV system. The main objective of the user/resident is to maximize the emergency power supply when the grid power is off. This objective is achieved by limiting the number of critical loads and by conserving energy. User interaction involves proper monitoring of PV generation and battery charge level and proper control of energy consuming electric loads. The procedure involves monitoring the customer's decision-making process when the utility power is interrupted for an extended period of time. It also involves observing the residents' behavior and energy using choices. In preparation for such study, we have set-up a simulation program in order to train the users to limit the number of the electrical loads and reduce the time those loads are kept on.

In this project, we study the performance of thin-film photovoltaic modules. These modules have very low efficiency. Now, different modules with higher efficiency are commercially available. They could have significant advantages in cost and/or efficiency and should be studied. Further, we will run computer simulations of the current system to investigate the effect a different type of photovoltaic module would have on the electrical generation capability and, thereby, the economic feasibility of the photovoltaic generation system.

North Carolina Central University

Investigation of Photovoltaic and Thermophotovoltaic Semiconductors at North Carolina Central University

Dr. J. M. Dutta (P1)

Our primary focus is to train selected students in research in fabricating and characterizing various bulk and nanophase photovoltaic materials. Cross-over phenomena on going from clusters to nanocrystals to the bulk is another focus of the research. The purpose of the program is to facilitate basic research and training in the energy-related technology. Over the last few years, at North Carolina Central University (NCCU), significant progress has been made in developing a semiconductor research program, supported by the National Renewable Energy Laboratory (NREL). Over the past few years we have been successful in acquiring several high power scientific apparatus, which will considerably enhance on-campus research capability for our students and faculty. Brief review of their applications to various scientific projects will be discussed and some of the important results derived will be presented.

One of our objectives has always been to establish an on-campus facility to fabricate quantum dots (QDs) and capability to deposit multi-layer thin films by Pulsed Laser Deposition (PLD) techniques. For that purpose, the chamber that will be used for the productions of QDs and the deposition of thin films has been designed and assembled at this time. A pulsed laser and a pulsed electron gun will be attached to the chamber and used to sputter a sample to a substrate. Its possible applications will be presented.

Low temperature crystallization and defect annihilation studies of thin a-Si films by exposure them to the FEL beam at certain wavelengths, and scanning over a range of different pulse durations and energies, has been continued during this reporting period. Two sets of 200 μm thick samples, one set of a-Si:H deposited on glass by hot wire deposition method at NREL and the second set deposited on mono crystalline Si substrate were exposed to 5 μm IR radiation at Vanderbilt University FEL. Intensities were chosen to be 2.4 KJ/cm^2, 4.8 KJ/cm^2, and 7.2 KJ/cm^2. The structural, optical, electrical and other properties were measured before and after exposure. Our preliminary results from Raman analysis confirm our earlier results on the improvement in the Short Range Order (SRO) and intermediate Range Order (IRO) after irradiation with the peak power density between 100 MW/cm^2 and 1000 MW/cm^2. At power lower than 100 MW/cm^2 the effect was not observed and at 1000 MW/cm^2 the process of crystallization starts. Details will be presented at the meeting.

Capacitance measurements of depletion layers in semiconductors are widely used in the characterization of electrically active levels due to the presence of impurities and point defects. By time resolved capacitance spectroscopy, “Deep Level Transient Spectroscopy,” (DLTS), electronic properties of such levels, activation energy, the carrier capture, and emission processes can be studied directly. DLTS also permits to gather information on trap concentrations, depth profile of the trap concentration, and others. We used DLTS for investigation of deep levels in polyciystalline Edge-defined Film-Fed Grown, EFG silicon (low-cost solar cells), as well as monociystaline Czocharlski and Float Zone silicon. Some of our recent research on EFG samples will be presented. Recently we have acquired a DLTS apparatus, made by Sula Technology Corporation. Its performance characteristics will be presented.

One of the promising approaches to improve the efficiency of solar cells is to employ multilayers, in which, the individual solar cells are stacked on top of each other to maximize the range of absorption in the solar spectrum. For example, a four-junction combination[i]; an AlGaInP (Eg=2.0eV) top cell; a GaAs (Eg=1.43eV) second-layer cell; a third-layer of GaInPAs (Eg=1.05eV) and a Ge (Eg=0.67eV) substrate as the bottom cell; has a theoretically predicted efficiency of 42%.

Most of the methods for growing multilayer thin films rely on epitaxial layer deposition on a variety of substrates at higher temperatures. Between various thin film deposition techniques, Pulsed Laser Deposition (PLD) using laser pulses of nanosecond duration carries the advantage of having high kinetic energy particles available for film deposition.[ii,iii] The high kinetic energy of the ablation species contributes to better quality of epitaxial layers, which are deposited at a much lower substrate temperature compared to other techniques. For example, smooth epitaxial Ti doped sapphire films have been reported at a substrate temperature as low as 650 ^{o}C by PLD in contrast to 1200 ^{o}C by other techniques.[iv,v] Film deposition at lower substrate temperature will be of interest to multilayer deposition in order to minimize the interdiffusion of species between different layers. Additionally, the thermal strain developed between layers during the cooling to room temperature can be reduced. The relatively simple experimental geometry of PLD enables to use appropriate background partial pressure both to maintain the film stoichiometry and to appropriately moderate the kinetic energy of the ablated species[vi] for better epitaxial film quality.

We are currently in process of developing a PLD and pulsed electron gun facility in NCCU and deposit individual layers of AlGaP, GaAs, GaInPAs and other layers of related interest followed by multilayers. Thin films will be deposited under different laser fluence and background conditions in order to characterize the role of kinetic energy of the depositing species on the film-substrate interface stresses. Insitu monitoring of epitaxial growth by reflection high energy electron diffraction (RHEED) will reveal structural information of the epitaxial growth after each laser pulse during early stages of epitaxial film growth.[vii] The RHEED information will be compared with the results of Raman spectroscopy described in the next section and the interface between heterolayers will be modeled. Deposition of ultra-thin films and their characterization as a function of film thickness will be undertaken. Film deposition on different substrates will be carried out in order to provide more experimental data for numerical computation and modeling of the film-substrate residual stress as described in the above sections.

The key technological challenge of GaAs film formation on Si substrate is the large stress at the interface due to lattice mismatch.[viii] Characterization of GaAs-Si interface versus film thickness, as an experimental parameter, will be done on the films deposited by PLD and pulsed electron gun technique. Similar work will be undertaken by introducing a thin buffer layer, such as $SrTiO_3$, which has an intermediate lattice constant between GaAs and Si. The expected outcome will help towards low cost solar cells development, and more versatile Si wafers in place of Ge. Apart from providing avenues for the research goal, in addition the NCCU students will be exposed to the NCCU state of art thin film deposition technique.

One of the problems encountered by PLD are the particulates observed during ablation use of nanosecond (ns) laser pulses. A major source of particulate emission from the target is the resolidification and the recoil pressure below the vaporizing front in the molten volume. The thermal diffusion depth, a function of the laser pulse width, is very small when a pico second (ps) pulse is used for ablation, if compared to ns pulses. This produces much smaller molten volume with a large temperature gradient and hence can reduce both the particulate emission[ix] and the ablation threshold.[x,xi] A typical micro pulse energy of 1 mJ per pulse at 1 ps width corresponds to an instant power of 1 GW, an appreciable value for laser ablation studies. We will also explore the wavelength tuneability of FEL that will provide advantage of selecting appropriate wavelength for ablation and the high repetition rate will enables much higher deposition rates compared to excimer lasers. High deposition rate enables to have longer target to substrate distance, and to obtain spatially uniform thin films over a large substrate area.[xii] However, the physics of laser ablation and thin film deposition using ultra short laser pulses is still not well studied. We will later upgrade our facility to deposit thin films and to characterize the laser ablated species by time of flight mass spectrometry technique and carryout deposition of different layers and multilayers towards developing high efficiency solar cells. We will compare the films deposited using nanosecond laser pulses from excimer laser and (sub) picosecond electron gun pulses and laser pulses from FEL.

In conjunction with several experimental techniques applied to investigate the performance characteristics of the solar cells, we also performed theoretical studies and developed computer simulation to understand their electrical properties. Brief summary of some of the theoretical work we undertook will be presented.

Synthesis of high efficiency solar cells discussed above has still to be demonstrated. One of the main technical problems is the stress that appears, because of mismatch in the lattice between various materials. Because of the differences in the thermophysical properties between films, quantum dots, and substrate materials, residual stresses are introduced during and after cooling down from the growth temperature to room temperature. This, plus the variations of growth conditions and fabrication techniques can cause defects and micro-structural changes in semiconductor hetero-structure devices. The electrical, optical, photovoltaic properties and device lifetime can be detrimentally affected. For example, dislocations formed at the interface will affect the material transport properties. Band gap variation with pressure (for materials such as CuInTe2 , $\partial Eg/\partial P \approx 53$ meV/GPa) (xiii) has been widely observed for semiconductor materials. The electron mobility also changes with the residual lattice strain (xiv).

For that reason we started with a systematic study of residual stresses, their effects on the electronic and optical properties in multilayer thin films and quantum dots devices. The comprehensive investigation of residual stress, thermophysical properties, and failure mechanisms of heterostructure devices can provide the optimal conditions for growth and fabrication of higher efficiency solar cells. It can also help us understand the effects of lattice mismatch and thermal residual stresses on the electronic, transport, and photovoltaic properties.

Three-dimensional semiconductor quantum ring is studied under the energy dependent quasi-particle effective mass approximation. The confined energy problem is solved numerically by the finite element method within the kp-perturbation theory in a single subband approach. The influence of the quantum ring geometry on energy states and the electron effective mass is investigated.

The quantum ring located on the top of the substrate is considered. Geometrical parameters of QR are the height H, radial width ΔR, and inner radius R_1, where H/ΔR < 1 (wide ring). The discontinuity of conduction-band edge of the QR and the substrate forms a band gap potential, which induces confinement electron states. The energy dependence of the electron effective mass is defined by the Kane formula [1]. This nonparabolical approximation leads to the nonlinear Schrödinger equation, which was solved by the iteration procedure using the finite elements method (FEM) within the PDE MATLAB toolbox. For the simulation the following typical QR/substrate structures with experimental parameters taken from [2] were chosen: InAs/GaAs, Ge/Si, CdTe/CdS. Analysis of the results of numerical calculations shows that the ground state energy of QR can be best approximated as a power function of the inverse values of the height and the radial width: $E \approx a\left(\frac{1}{\Delta R}\right)^{\gamma} + b\left(\frac{1}{H}\right)^{\beta}$, where the coefficients γ=3/2 and β=1 were obtained numerically by the mean square method. An example of this relation is illustrated in Figure 1.

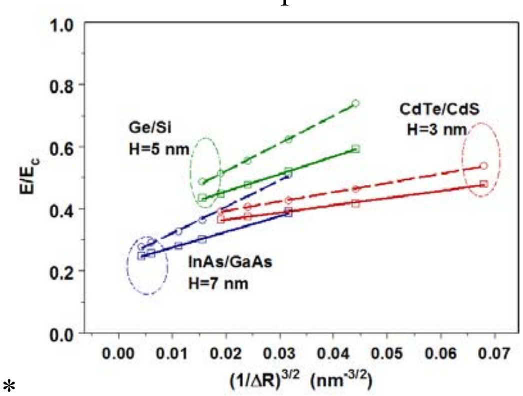

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Figure 1. Electron confinement energy of QR in the parabolic (dashed lines) and nonparabolic (solid lines) approximation.

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North Carolina Central University Research Program on High Efficiency Photovoltaic Solar Cells

Dr. Branislav Vlahovic

Our main goal during the last several years has been to build an experimental infrastructure at the physics department: to install DLTS, Hall Effect (Fig. 1), AFM, Raman, PL, Pulsed electron gun, and to build the chamber for the pico second pulsed electron and laser deposition. Since our budget was limited, it did not allow us to purchase the systems already assembled; so we have built them from the components, which has required considerable additional work, for instance, programming and connecting electronic hardware. However, despite of the time consuming tasks of building the laboratory, we have succeeded in performing significant active research.


Figure 1. DLTS and Hall Effect built from the components by NCCU faculty.

The study of material modification by Free Electron Laser has resulted in successful improvement of a-Si intermediate and short range order by 3.5 μm irradiation, which may lead to an industrial application. We also carried out research on thin films and quantum dots deposition with pulsed laser beam on various substrates at various substrate temperatures and with various beam energies and time structures. This work was done in collaboration with Indira Gandhi Center for Atomic Research, and Fisk University. We have conducted significant material characterization and study of material damage in semiconductors induced by radiation with the combination of opto-electrical and nuclear methods. The improvement of nuclear methods for semiconductor characterization is part of the awarded NREL grant. Our department participated in the development of Rutherford Back Scattering (RBS), Elastic Recoil Detection Analysis (ERDA), Induced Beam Ion Current (IBIC), and PIXEL. In addition, we made quantum dots by ion implantation with our collaborators in Zagreb University and in University of Surrey, and we also prepared first quantum dots by chemical methods from the precursors developed at NCCU chemistry department. We have performed an extensive analysis of these quantum dots by DLTS, AFM and Raman. Some of those results were presented at international conferences and submitted for publication.

It is very important to emphasize that during the last three years we successfully accomplished three projects and obtained attention from the international community.

1. We used our experience with silicon microstrip detectors[xv,xvi,xvii,xviii] and successfully designed, constructed and built the Polarimeter for High Energy Photons. It was a challenging project attempted by a number of research groups during the last 60 years. However, with our original approach, we are the first and the only group that successfully solved the problem[xix,xx]. This demonstrates that our group is able to handle the most complex projects successfully, from the original idea to the final product. The instrument we built (by funds received through a NSF grant and additional support (from JLab) is one of the key experimental setups in Jefferson National Laboratory, Newport News, Virginia (see Fig. 2).
2. Our successful theoretical accomplishments during the same time are very impressive. Having an original approach, our group has rigorously solved the Faddeev equation above breakup for a few body scattering problem with inclusion of Coulomb force[xxi,xxii,xxiii,xxiv]. To demonstrate the level of complexity, it is enough to say that many groups around the world, including computational groups at Los Alamos, Bochum, and Pisa, worked on the same problem for the last 30 years.
3. We recognized quickly that the number of problems in nanotechnology require solution of almost identical set of equations that we have solved in a few body physics. It took almost a year to modify the few body computer codes and to build perhaps the most complex and rigorous computer program for calculations in nanoscience. With newly developed computer code we can rigorously calculate the charge transport through quantum wires and quantum dots with multilayer structure, and when thermal stress and materials band gaps are used as input potential[xxv,xxvi,xxvii,xxviii]. One of the goals is to further improve our computer simulation program by introducing more realistic potentials and by including higher partial waves in calculations.

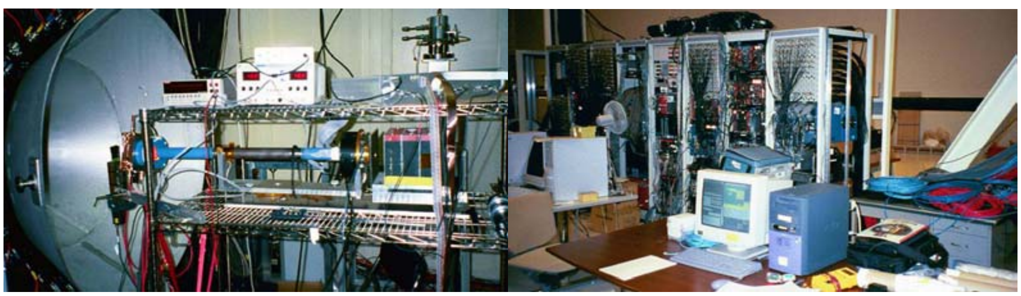

Figure 2. Polarimeter for High energy photons developed by NCCU.

We anticipate that the possible objection to our research may be that it looks somewhat disjointed, that we are doing a number of unrelated research projects. Our history of approaching many problems at the same time and successfully accomplishing all of them is our best answer. We would like to emphasize that all ongoing tasks in our previously awarded NREL grant were effectively completed. We admit that we would like to continue with all current projects. All of these projects are internally connected and related to the proposed program.

1. The research, which we are planning in just awarded NREL proposal, is focused on one subject: development of high efficiency photovoltaic cells using new advances in nanoscience on thin films and quantum dots pulsed electron and laser beam deposition. To demonstrate connections between our theoretical and experimental research, and various experimental methods, which will be used, let us summarize the research that we proposed in following several points:

2. The thin films and quantum dots will be produced by pulsed pico second electron and laser beam deposition under various depositional parameters. The power of the electron and laser beam will be varied as well as the temperature, and the angle of the target and substrate. The effect of the dot size and material composition will be also studied.

3. Extensive characterization of the produced thin films and quantum dots will be performed by AFM, DLTS, Raman, PL, TSC, FTIR, Induced Beam Ion Current (IBIC), and Rutherford Back Scattering (RBS) methods.

4. Computer simulation of the stress between thin films and quantum dots layers and substrate will be performed. The effect of the stress on the charge transport through the thin films and quantum dots will be calculated. The experimental and numerical modeling results will be compared, which will provide better understanding of various factors affecting the quality of thin films and quantum dots.

5 The optical trap method will be developed and used to isolate and simultaneously characterize, by optical methods, single quantum dots, as well as the aggregates of the encapsulated quantum dots. The optical trapping will also be applied to narrow the size distribution in quantum dots and to assemble them into 2-dimensional periodic arrays.

6. Thin films and quantum dots will be produced by other methods, which include chemical deposition from precursors and ion implantation. The characteristics of thin films and quantum dots produced by these methods will be compared by those produced by pulsed electron and laser beams.

We are proposing an ambitious project that will involve complex experimental and theoretical work. However, we are confident that all proposed tasks will be accomplished. New experimental setups and computer programs will be developed and the experiments and calculations will be performed. The proposed research is very focused and designed to result in better understanding of formation of the nanostructures, thin films, quantum dots and wires from both experimental and theoretical points of view. Ultimately, it will lead to our final goal of producing high efficiency photovoltaic cells.

Numerical Simulation of Residual Stresses and Electronic Properties Photovoltaic Cells

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The fabrications of high efficiency solar cells, such as multi-junctions and quantum dots, are usually accomplished by growing nanometer sized semiconductor materials on various substrates. Residual stresses are created in these devices because of the differences in thermoelastic properties between the deposited materials and the substrate materials. In addition, the operation of these solar cells is usually in a very high temperature environment. All these factors will affect the electrical, optical, photovoltaic properties. The performance of the devices and their lifetime can be detrimentally affected.

To understand the relationship of various conditions, such as growth temperature, geometric structure, composition, operating environment, a new factor, operating temperature, has been included in our numerical simulation effort. The impacts on electronic states and microstructures were studied. Undergraduate students are involved in most stages of the research work in numerical simulations.

The results from the numerical simulation will be presented. The comparison with available data and literatures will be provided.

PULSED LASER DEPOSITION OF MICROCRYSTALLINE SILICON

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Microcrystalline silicon thin films are deposited on glass, quartz, and Si(111) substrates by pulsed laser deposition. It is shown that the emission of the particulates from Si target during laser ablation, although traditionally undesirable, can be successfully utilized to produce both crystalline, and crystalline/amorphous Si films. Experimental conditions for microcrystalline and amorphous phase formation, and the results of the film characterization are discussed.

The second harmonic (532 nm, TEM00) beam from a Q-switched Nd:YAG laser (Continuum, model NY62) with a pulse width of 8 ns, pulse energy of approximately 40 mJ, and repetition rate of 10 Hz is used for ablation of the ultra-pure Si targets onto single crystalline silicon substrate. Irradiated power on samples was varied from 1.8x107 to 8.9x108 Watts/cm2. The second harmonic was chosen because the pulse of the 1064 nm wavelength from the Nd:YAG laser produces larger particulates of the order of several microns, whereas the third and fourth harmonics provide substantially less pulse energy. The top few layers of the Si targets are pre-ablated in a H2 atmosphere in order to remove the oxide layers. Cleaned Corning 7059 glass, amorphous quartz, and Si (111) substrates are used with a target to substrate distance of 50 mm. The H2 background pressure and the substrate temperature were varied from $5x10^{-3}$ Torr to 1 Torr and from 25^{o}C to the 200^{o}C, respectively. Samples were also deposited in vacuum ($2x10^{-6}$ Torr). Finally, after deposition some samples were annealed at 250^{o}C under 1 Torr of H_2 atmosphere. Figure 1 and Figure 2 display the atomic force microscope (AMF) pictures of the thin films deposited at 25°C and 200°C on Corning 7059 glass substrates corresponding to a laser power density of $1.3x10^8$ W/cm^2.

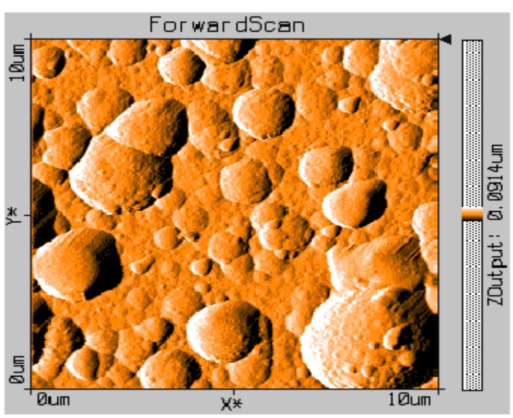

Fig.1

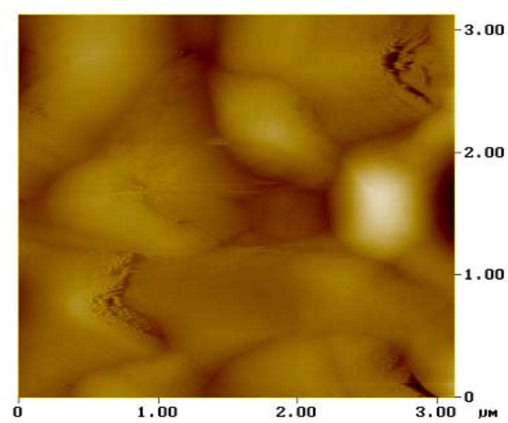

Fig. 2

Residual Stresses Modeling In Multi-layer Thin Films

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Semiconductor or ceramic thin films are fabricated by deposition of materials on various substrates. Due to the differences in thermoelastic properties between the film and the substrate materials, residual stresses will be generated in the devices. Various techniques have been proposed for minimizing the residual stresses in the films. The processing of functionally graded materials is one of the techniques that can be used for optimizing the residual stress. Numerical method is applied to model the distribution of the residual stresses in the multilayered thin films. The comparison between the multilayer thin films and the functional graded materials will be discussed.

North Carolina Central University

A Broadened Horizon: High Performance PV for a High Performance World

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As the world scrambles to find alternative sources of energy to replace our rapidly depleting supplies, we come upon the notion that the question is not whether we will be able to supersede our current energy source, but rather what new source will supersede it. Photovoltaics (PV), or the conversion of sunlight into electricity, is a strong candidate in the race to become the world's leading energy source. However, there is much work to be done to make it more cost competitive. Building a more efficient solar cell that generates more electricity while reducing energy costs is what the National Renewable Energy Laboratory's (NREL) High Performance PV Project is all about. Efficiency refers to the amount of power generated based upon the input of sunlight energy. The focus of NREL's High Performance PV Program is polycrystalline thin-film solar cells and III-V multi-junction concentrators. For concentrator cells, the metal grid contacts are particularly important because of the large currents that flow through. The goal of this project is to develop improved concentrator grids by increasing the thickness of the metal from 1µm to 3µm. This can be achieved by improving the process (termed "photolithography") by which the metal grids are crafted. The existing processes for photolithography cannot accommodate the application of a thicker metal grid, thus the potential output of the solar cell is limited. Enhancing the photolithography process can determine a significant increase in overall cell efficiency. Accomplishing these goals will allow photovoltaics to take its place in the world as a leading source of renewable energy.

Southern University and A&M College

ABSTRACT ENERGY CONVERSION AND STORAGE DEVICES: SOLAR ENERGY EDUCATION AND RESEARCH

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This DOE-NREL-MURA project at Southern University and A&M College, Baton Rouge covers the studies of nanotechnology for highly efficient energy conversion and storage, for creation of nano-functional materials/systems for high energy savings and new environmentally friendly systems such as batteries, fuel cells and heat reflecting and self-cleaning materials. In this three year project, we have initiated our effort to accomplish the following specific tasks: 1) Development of nano-structured photocatalysts with visible light response for water splitting, 2) Development of nano-structured anodes and cathodes for high energy and power density devices such as PV powered Li-ion batteries and supercapacitors, and 3) Development of dense membranes for zero emission IT-SOFCs.

The photocatalytic splitting of water into hydrogen and oxygen using solar energy is a potentially clean and renewable source for hydrogen fuel. Visible light response photocatalysts in which charge separation and reactive sites for H_2 and O_2 evolution are controlled with specific nano-structure are developed in order to produce hydrogen from water using solar light. This splitting can be achieved either in a photoelectrochemical (PEC) solar cell, or by applying photovoltaics cells which directly utilizes solar radiation for electrolysis of water into H_2 and O_2. Photoanodes of a new type of highly ordered nanostructured Hematite (a-$Fe2O_3$) are prepared and characterized using non ionic surfactants. Strategies to make these materials into efficient photoanodes will be discussed. We also show that doping of indium-tantalum-oxide with nickel yields a series of photocatalysts, $In_{1-x}Ni_xTaO_4$ (x = 0–0.2), which are expected to be used in the photoelectrochemical production of hydrogen experiments.

Nanocrystalline and mesoporous metal oxides such as NiO_2, Fe_2O_3, TiO_2, SnO_2, Sb:SnO_2 RuO_2, SrRuO3, and $La_xSr_{1-x}Ru_{1-y}Mn_yO_3$ exhibiting large surface areas, high metallic conductivities, and pseudocapacitance are being explored and synthesized to be as supercapacitance electrodes. We report the enhanced capacitance found in these materials and their role in the development of hybrid power source, a supercapacitor combined with a rechargeable battery. Supercapacitor (SC) is an attractive device for high power applications. When incorporated into a portable power source that relies on rechargeable batteries, they add the capability for meeting the burst power demands in many applications, such as electric vehicles, wireless communication (e.g. radios and sono buoys), lasers and power tools. Two different charge-storing mechanisms have so far been utilized for SC. The double-layer (DL) storage mechanism involves charge separation at the electrode-electrolyte interface, while the faradaic redox reaction of surface species gives rise to the so-called “pseudocapacitance”.

To make Solid Oxide Fuel Cell (SOFC) commercially viable for environment-friendly energy generation, it is of considerable interest to develop new synthetic techniques for large scale, cost effective preparation of materials for application as cathode, anode and electrolyte. The main focus of this project is to fabricate dense ceramic membranes on porous crystalline substrates. We are employing solution combustion technique, microwave assisted route, mechano assisted (ball milling) and pulsed laser deposition techniques to synthesize $LaCrO_3$, $LaNi_{1-x}Fe_xO_3$, $Gd_{0.1}Ce_{0.9}O_{1.95}$(GDC) and perovskite based electrolytes like LSGM which are promising materials for application as interconnectors, cathodes, electrolytes and anodes respectively at operating temperatures of about 650-800°C.

This project will support three students during the academic year and two students during summer to work in the solid state ionics laboratory at Southern University.

Temperature Distribution through Optical heating

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This paper will discuss factors of non-uniformity and incident lighting in temperature distribution within the production of solar cells. Non-uniformity or variance in temperature distribution is a major counterpart in understanding and applying it to temperature uniformity, basically to keep the temperature constant. The linear placement of the thermocouples gives continuous temperatures whereby temperature distribution in practicality is not uniform. By using incident lighting as opposed to regular lighting, the wafer can heat simultaneously and evenly. This method incorporates all three fundamentals of heat transfer in an efficient and evenly distributive manner in the production of the silicon wafers. Conduction can be seen by the absorption of the heat with incident lighting, while reflectance from the wafer displays the convective transference of heat across the top of the wafer. Transference of heat from the light source to the wafer along with the wafer emitting heat towards the atmosphere is proof of the radiative heat transfer. Using non-uniformity and incident light implementation applied to this type of optical heating will be successful in solar cell production.

National Household Power Projections along with the Potential of Solar Methanol Production

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Today's focus on renewable energy is constantly expanding at a considerable rate. One topic that has not yet been fully explored is the amount of power that can be mass-produced by the nation if each rooftop were covered with PV cells. By unearthing this technology, it would provide a chronological prediction of the power supply for particular time eras. Besides that, there is another technology that is trying to break through in the renewable field and it is termed solar methanol. The term solar methanol is described as using a synthesized method of producing methanol from biomass production in conjunction with electrolysis of water. Contrary to skepticism, there has been research into its viability in today's market compare to the solar hydrogen economy. Insights into their concept generation, practicality, feasibility and cost competitiveness to other fuels for energy are investigated.

UV-VIS-NIR DIFFUSE REFLECTANCE MEASUREMENTS OF NANOCRYSTALLINE PHOTOCATALYSTS

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The present study aimed to directly measure the absorption edge and band-gap energies of these nanostructured materials, based on the onset of UV-Vis diffuse reflectance spectra using a Cary 500 spectrophotometer. The absorption edge or band edge is defined as the transition between the strong short-wavelength and the weak long-wavelength absorption in the spectrum of a solid, generally a semiconductor. The spectral position of this edge is determined by the energy separation between the valence and conduction bands of the material in question. In the case of transparent solids, the absorption edge can be measured using transmittance techniques. Diffuse reflectance measurements provide a more appropriate means of measurement for powdered materials. One driver for this research is the perceived potential for application of nanostructured photocatalysts for hydrogen generation experiments. Particles of a nanometer size exhibit unique properties such as quantum effects, short interface migration distances (and times) for photoinduced holes and electrons in photochemical and photocatalytic systems, and increased sensitivity in thin film sensors. Photoelectrochemical processes at semiconductor colloid/electrolyte interfaces, such as the splitting of water and reduction of carbon dioxide, have received special attention because of their possible application for the conversion of solar energy into chemical energy. This investigation forms part of the research program being undertaken by the Department of Energy-MURA program.

The diffuse reflectance accessory (DRA) was installed into the Varian Cary 500 UV-Vis-NIR Spectrophotometer and aligned. The 'Scan' software was opened and the appropriate operating parameters set in the 'Cary' window. In addition, the 'SBW' (spectral bandwidth; nm), 'Beam mode' and 'Slit height' were set to '2.000', 'Double', and 'Reduced' respectively in the 'Options' window. Finally, 'Zero/baseline' correction was selected in the 'Baseline' window. Diffuse reflectance spectra of the nanocomposite materials investigated (including precursors). The results obtained for the precursor 'semiconductor' material TiO_2 are in general agreement with results reported previously. Band gap values for TiO2 can vary depending on particle size of the material, with smaller band gap values indicative of relatively densely packed crystalline structures.

Hawaii Electric Company (HECO) Solar Water Heating Program: Analysis of Solar Water Heater System Installation Inspection Data and Warranty Claims Data

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Since 1996, HECO (and its subsidiaries), the investor-owned utility that provides electric power for all of Hawaii, has been conducting a solar water heating system market development and rebate program targeted at individual homeowners. The principal objectives of the program are to: (1) make additional progress towards meeting the Renewable Energy Portfolio Standard established by Hawaii for the production of electric power in the state; and (2) reduce peak demand requirements for power. To date, over 24,000 homeowners have participated in the rebate program. The rebate is for $750- $1000 towards the installed cost of the system. This is in addition to a state tax credit of 35% of the system's installed cost. However, in order to qualify for the rebate, the system must be purchased from and installed by dealers and installers on HECO's "approved list". In addition, the system's installation has to pass a HECO inspection process – conducted by an independent inspector -- that involves meeting 45 installation requirements (e.g., clearance from roof, tank sensor connection, roof penetration sealing, etc.). In addition to the rebate, HECO also provides a five-year warranty on the systems procured as part of its program. This paper: (1) provides engineering descriptions of the three principal types of solar water heaters available via the HECO program; (2) documents a statistical analysis of the approximately 250 system inspection failures for installations done in 2001; and (3) documents a statistical analysis of the approximately 450 warranty claims that were made during the period 1996 – 2004. The paper ends by proposing recommendations regarding research and development efforts that might be conducted to ameliorate the installation problems that have been encountered and the system operational problems that have resulted in filing of warranty claims.

Design and development of a photoelectrochemical reactor for removal of hexavalent chromium in Louisiana Water Ways

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Photocatalysis has been demonstrated to be an inexpensive and effective method for treating a wide range of pollutants in both water and air, and the use of solar radiation as an energy source can significantly reduce the costs of operating a photocatalytic reactor. There has been a vast amount of laboratory based research in this field reporting the successful treatment of organic and inorganic aqueous pollution. Most workers utilise the catalyst in the form of an aqueous colloidal suspension which is irradiated with either solar or uvA source. The use of a suspension requires post treatment removal of the catalyst by a solid-liquid separation. Alternatively the catalyst may be immobilised on a supporting substrate. There are various titanium dioxide preparations commercially available and conflicting reports as to which preparations are the most efficient as photocatalysts. The aim of this work was to identify which of selected commercially available titanium dioxide preparations showed the highest photocatalytic efficiency when immobilised on titanium foil. The possibilities and the limits of photo(electro)chemical pollutant degradation in aqueous solutions based on transition metal oxide semiconductor photocatalysts in the form of powder suspensions, and nanostructured thin film electrodes are discussed.

Frequently, metal ions are introduced into waterways by industry as waste from various processes. Many of the metal ions are toxic to humans, and their release must be monitored and controlled carefully. A metal ion that can be a pollutant is the hexavalent chromium ion. There are two natural forms of ionic chromium, the hexavalent ion, Cr(VI) and the trivalent Cr(III). Cr(III) is much less toxic than Cr(VI) and seldom found in potable waters. Cr(VI), however, is toxic to humans and is found in water. It has been shown to toxic when in aerosol form causing damage to the skin and upper respiratory system and causing lung cancer1. The toxic effects from Cr(VI) in drinking water are not well documented, but it is a suspected carcinogen. The experiment outlined here is a test for the presence of Cr(VI) in water that uses a sensitive colorimetric reagent. We have determined the level of Cr(VI) in both the local tap water and some polluted "industrial" waste water. The experiment also investigates some methods by which industry can lower Cr(VI) concentrations prior to releasing their waste water.

Optical Processing: Using the Optical Processing Furnace to Analyze the Relationship of Novel Temperatures and Position Distribution of Light Source and Wafer

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Optical Processing (OP) uses spectrally selected light to heat semiconductor wafers allowing some photonic effects to be preserved. Thus, illuminated and unilluminated regions of the wafer can have different reactions (even though their temperatures may be similar). The photonic effects at the interfaces and in the bulk of the semiconductor are used to lower the processing temperature for semiconductor device fabrication. Creating a thermally activated reaction, there is a local melt at the illuminated semiconductor-metal (S-M) interface forming an alloyed ohmic contact of very low contact resistivity. The process performed in an Optical Processing Furnace (OPF) is particularly useful for fabricating photovoltaic and opto-electronic devices. Since light is only absorbed by the wafer, OPF is typically a “cold wall” process. One of the applications of OP induces controlled reactions at a Si-Al interface that removes impurities from Si (a process known as impurity gettering). This paper describes how the OPF reaches novel temperatures between 800°C and 1000°C; as well as, focus on the relationship between the temperature and position distribution of lights and wafer.

University of Texas, Brownsville

Overview of the Tonatiuh Software Development Effort

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The objective of the work that is undergoing at the University of Texas at Brownsville under the DOE-NREL Minority University Research Associate (MURA) Program consists in the design, development, implementation, verification and validation of Tonatiuh: an open-source advanced object-oriented program, that using distributed computing, Monte-Carlo Ray tracing, and the best 3-D user interface technologies available today, will provide a sophisticated and efficient software environment for the design and analysis of solar concentrating systems.

It is intended that Tonatiuh will meet or exceed, among others, the following requirements:

a. Provide a unifying computational paradigm for the simulation and analysis of virtually any type of solar concentrating system that may be envisioned.

b. Be extremely user-friendly, easy to adapt, expand and maintain.

c. Be able to take advantage and efficiently handle any computer power available to it.

By pursuing the research objective stated above, the two undergraduate students involved in this project will be exposed to a large and fundamental body of knowledge related to solar energy technologies.

The paper presents an overview of the Tonatiuh software development effort and of its status.

Anti-Reflective Coating Thickness Variation in a Single Measurement Using New GT-FabScan 6000 Reflectometer

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This paper will introduce one of the latest features of the GT-FabScan 6000 reflectometer. The reflectometer uses reciprocal optics for its evaluations of solar wafers. The new configuration of the reflectometer includes a camera attachment that provides accurate and high-speed mapping of a solar cell. Due to this new ability, the analysis and design of a solar cell are exponentially facilitated. Thickness variation of anti-reflective (AR) coating is made possible making only one measurement for a 6 x 6 inch wafer. Results can be obtained using either mode offered by the GT-FabScan 6000 reflectometer: the image or reflectance spectrum mode. However, this paper will focus mainly on the imaging mode. Theoretical AR Thickness results will be obtained using the data generated by the *PV Optics* software. This data will be multiplied by a conversion factor in order to generate an AR Thickness vs. Position plot. Results yielded by the new system will be compared to those from the converted data.

Development of an Efficient Polishing Procedure for Cadmium Telluride and Cupper Indium Selenide using Atomic Force Microscopy

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In this project, the surface of Cadmium Telluride and Cupper Indium Selenide are analyzed as the materials are polished utilizing a Precision Polishing Machine. Different polishing compounds are utilized in the polishing process to try to develop an efficient procedure that will help to obtain the flattest possible surface of the materials. The difference in roughness as the materials are processed is measured with the help of an Atomic Force Microscope. Before the materials are put under polishing treatment, it is necessary to learn and understand the basic concepts of Scanning Probe Microscopy (SPM). SPM microscopes are instruments used for studying surface properties of materials from the atomic to the micron level. During the conduction of this experiment, Atomic Force Microscopy, which is a branch of SPM, is utilized to analyze the changes of the surface of the materials as they are polished. The theory of AFM was studied to have a better understanding of how the machine used in the project works. The system utilized during the conduction of the experimentation is the Autoprobe LS a system manufactured by Thermo Microscopes. Utilizing the microscope, several images of different magnification are taken and saved before the samples are polished. With the help of the software that is used to control the system, the roughness and other characteristics of the samples are measured and recorded. The materials are then polished using different diamond polishing compounds on the precision polishing machine. The polishing stage is developed in intervals; in other words, the materials are gradually polished to study the change in the surface. The roughness of the surface of the samples is measured and recorded after each polishing step. This same procedure will be repeated using different polishing compounds to determine the more efficient method of polishing these materials.

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My name is Kara Broussard and I currently attend Southern University A &M College (SU) at Baton Rouge. I am mechanical engineering major, vice chair of SU chapter of ASME and member of SAE (Society of Automotive Engineers) and co-organizer of ASME Soccer in the afternoon. Current projects that I am working on are NASA Moonbuggy Competition and ASME Student Design Competition. Also, I enjoy drawing, designing, playing basketball, soccer and swimming. As for academics, I have been on the dean's list since freshman year, received award for highest GPA (2000), and recognized as an All American Collegiate Scholar.